engineering education

and a lifetime of learning

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ENGINEERING EDUCATION AND A LIFETIME OF LEARNING

A Study by the Stanford-Ames Summer Faculty Workshop
in Engineering Systems Design

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FOREWORD

This report is the result of an eleven-week study sponsored jointly by the National Aeronautics and Space Administration and the American Society of Engineering Education. The participants in the project, which took place at Ames Research Laboratory during the summer of 1974, were nineteen faculty members from various schools and universities across the country. This study was the ninth of a series of similar summer programs and was conducted by Stanford University and Ames Research Laboratory. The programs have three purposes: (1) to introduce engineering school faculty members to system design and to a particular approach to teaching system design, (2) to introduce engineering faculty to NASA and to a specific NASA center, and (3) to produce a study of use to NASA and to the participants.

The initial goal of the group was to design an engineering education system for the San Francisco Bay Area which would better integrate the various agencies involved in and benefiting from engineering education. For a number of reasons, the final report does not focus upon the Bay Area. Some of these reasons are the transient nature of students, faculty, and engineers, the atypical nature of the Bay Area, or for that matter, of any geographically small area, the geographical origins of the participants, and the national nature of the problem. This report therefore speaks to engineering education in the U.S., although it is certainly pertinent to engineering education in the San Francisco Bay Area, or in any other region. Early in the study, the group concluded that research and graduate education was perhaps in better condition than undergraduate education and teaching. This conclusion reflected in some sense the interests of the group and in some sense the institutional viewpoint that the group was taking (graduate education and research occurs more in independent fiefdoms within schools than in the overall institutions). The study therefore concentrates upon undergraduate education and teaching, although this bias is not meant to imply that the group considers research and graduate study less important to engineering education.

Thanks are in order to all of those agencies and individuals who contributed to this study. Our initial speakers were uniformly interesting, informed, and exciting. The hospitality and cooperation of Ames Research Laboratory was outstanding. We would especially like to thank Hans Mark, the Director, Leonard Roberts, Director of Aeronautics and Flight Systems, Al Chambers, Research Assistant to Dr. Mark, and Tony Cook, Technical Assistant to Dr. Roberts. We would like to thank also those people in industry and schools who had the patience to answer our innumerable questions. Last but not least, special thanks are due to Linda Ploeg, the unbelievably energetic and competent secretary of the group and Inga Lof, who is responsible for the typing and organization of this report.

INTRODUCTION

We can recognize many concerns which will shape the future of our society. Among these are energy, natural resources, environment, population, health, urbanization, housing, transportation, food, and war or peace. These forces will shape our institutions, our professions, and us as individuals. Because of the central role which technology has assumed in our culture, few parts of society will be more changed than those in which technology plays a role. Few institutions will have greater challenges than those industries, laboratories, and agencies which employ engineers except, perhaps, the educational institutions which educate engineers. Few professions will have more of a need to respond to future directions than engineering and few professionals will have a greater opportunity to contribute to a vital future than the engineer. With this in mind, we have proceeded to contemplate the future of society as it may affect engineering education and have been presumptuous enough to make recommendations.

Early in our study we came to two broad conclusions. The first was that engineering has chosen to exploit only a very narrow band in the total spectrum of technical education and in the process has excluded itself from many exciting and important problems, from many bright creative students and faculty, from the quantity of students needed to supply society's needs and to keep our educational plants filled, from badly needed financial support, and from a fully satisfactory social status and political base. We conclude in this report that engineering education should reject this narrow role and develop a broader one. There are many obstacles in the way, but they can be overcome by imaginative action.

The second conclusion we came to was the unsuitability of depending upon an engineering education which seeks to prepare an engineer for a lifetime career in a four to eight year period at the beginning of that career. Such a conclusion is obvious if one looks at the changing nature of knowledge, the lack of professional perspective of the typical student, or the changing nature of the typical career. We concluded that engineering education must be lifelong and recurrent. Appendix 2 is a longer and more detailed argument for this viewpoint.

As was mentioned in the foreword, the thrust of our study is with teaching and learning, not because we feel that research and service activities are secondary but because we believe that they are presently being done very well. Our emphasis is on the undergraduate and lower graduate years of education, not because we feel that the Ph.D. level is unimportant, but because we believe the number of problems is greater at the lower levels. We make recommendations that suggest institutional changes, not because our society and our profession are more perfect, but because we believe that the institution represents the most fertile source of potential change.

To predict the future with accuracy is not simple or, for that matter, always possible. Yet, if we are to plan for the future, we must somehow anticipate its characteristics. To do this, we have examined the trends in engineering education for the past 20 to 30 years and have identified some significant directions that appear to be shaping our future (Chapter 1). We have gone further and attempted to predict some future changes that will affect engineering education (Chapter 2). With a fervent belief that we can, through wise decisions and overt action, affect our destiny, we next state where we believe engineering education should be in the next 20 to 30 years (Chapter 3). Acutely aware that there are obstacles in our path and that strategies must be developed to overcome those obstacles, we have chosen five major obstacle areas to identify, attack, and overcome. They are: faculty attitudes (Chapter 4), the educational role and responsibility of industry (Chapter 5), funding (Chapter 6), institutional objectives and goals (Chapter 7), organizational structures (Chapter 8), and the influence of governmental, professional, and other agencies on engineering education (Chapter 9).

With this report, however, we do not rest our case. The issues are far too complex for 19 people to solve in 11 weeks. We ask that the effort here contribute to those discussions that go on in the hallways, offices, and conference rooms where engineering education is a topic of concern. We trust that the report that we have developed as a group will be helpful in developing a viable engineering educational thrust in the United States for the future and that what we have learned as individuals in contributing to the report will be influential in our home institutions.

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Part I

PERSPECTIVE ON THE FUTURE OF ENGINEERING EDUCATION

In which we examine current trends in engineering education, express our concerns for the future, and recommend new directions for engineering education.

Chapter 1

TRENDS IN ENGINEERING EDUCATION

Engineering education is presently entering a new era. The old era, which began in the 1940's, was characterized by the development of high technology, research oriented, science-math based curricula and was spurred on by the needs of defense, space, and industries (such as electronics) based on scientific phenomena. The new era is being formed by the necessity of applying technology more shrewdly toward the goal of improving the quality of life and conserving the finite resources of the earth. It is an evolution, rather than a revolution, since the sophisticated math-science based approaches of the past era will be continued. However, the perspective in which they will be developed and utilized will change.

The major trends that have developed since World War II support this view. This chapter summarizes those trends and comments on the directions engineering education appears to be headed in the next few years. The data which support the statements in this chapter are contained in Appendix 1, along with the pertinent references. This chapter generalizes on this data and does not contain references.

It is important to notice that in this report we are interested in engineers in the broad sense that they are employed and utilized by society. There is some semantic confusion here, since those involved in education in the engineering schools consider engineers to be graduates of ECPD (Engineering Council for Professional Development) accredited undergraduate curricula, of similar programs which are not accredited, or from graduate programs from institutions with ECPD accredited undergraduate curricula. Industry, however, and society in general, define an engineer more by function than by education. Thirty-eight percent of those employed as engineers have less than a baccalaureate degree and many of the remainder have degrees in fields such as physics, chemistry, or engineering technology. Society seems to be willing to consider an engineer as a person who works as an engineer, despite his degree.

It is also important to note that not all engineering education takes place during the four to eight years an engineer may spend in college, but is to some extent spread through his/her professional career. With these thoughts in mind, Chapter 1 examines trends in students, instruction, programs and curricula, cost and finance, and professional opportunities both inside and outside of schools of engineering for all those who are classified as engineers. From these trends we cannot but conclude that engineering education is, indeed, in a period of dynamic transition during which small inputs at the present time can result in large changes in future directions. We will suggest such inputs in the chapters that follow.

A. Inside Schools of Engineering

1. Students

The dramatically decreased enrollments in traditional engineering degree programs which began about five years ago surprised many engineering educators and have remained a cause for grave concern. Since the start of the decline in enrollment coincided with an economic recession and with major changes in defense and space funding and accompanied a dislocation in engineering employment, some engineering educators tend to look no further for the cause. Other factors, however, may be even more important. The changing enrollment pattern may reflect more fundamental changes in society, in the engineering profession, and in the attitudes and aspirations of young people.

The decline in enrollment in the traditional programs began in the late 1950's when the percentage of all college freshmen who entered engineering began to decline. This effect was masked from engineering educators by a coincident increase in graduate student enrollments and the availability of substantial federal funds to support research. Thus engineering education appeared to share in the phenomenal growth of higher education. Yet, records show that at the undergraduate level in engineering degree programs this definitely was not the case. By about 1969, however, graduate student enrollment and federal funding had levelled off or even dropped, and freshmen engineering enrollment began a sharp decline in total numbers, not just in percentage of students. It then became very clear that traditional engineering education was not sharing fully in the growth of higher education.

Many reasons for this enrollment decline in addition to the job market have been suggested. Alienation of today's students from technology and a consequent turning to people-oriented programs and professions, the relative difficulty of engineering programs, and poor career counseling are among them. Most important, perhaps, is the increasing number of options open to the student who wishes to prepare for a technically oriented career. Prior to World War II, baccalaureate programs in engineering and mathematics, physics, and chemistry provided nearly all technological manpower. Since then, tremendous growth has occurred in a variety of programs that contribute to technical manpower. These include certificate and two year associate degree programs for technicians, four year baccalaureate programs in engineering technology and industrial technology, and baccalaureate and graduate programs in new science areas such as statistics, computer science, nuclear science, environmental science, operations research, etc. Using a definition of engineering education which was consistent with society's definition of an engineer, all of this activity would be defined as engineering education and the enrollment drop would appear much less severe. Unfortunately, in our opinion, traditional engineering education has chosen or has been forced to occupy an increasingly narrow band of the total spectrum of technical education, and therefore it attracts students from an increasingly narrow band of all potential students.

The student typically attracted to traditional engineering is a white, middle class male who has completed a standard college preparatory program in high school wherein he excelled in mathematics and science. Prospects for returning to former enrollment levels by relying on this traditional source of students are not bright. Changing interests of high school students and changing attitudes toward rigorous courses have caused many bright students to abandon standard college preparatory programs that emphasize mathematics, science, English, languages, and history. Instead, they opt for more elective programs with a vocational or social science flavor. Thus, we can expect fewer white male students coming to college with this rigorous preparation, and, therefore, fewer who will find traditional engineering programs attractive. They may be interested in engineering technology programs and certainly will find they are welcome there.

Also noteworthy is the fact that the number of persons of college age, after years of continual increase, will soon decline and will not return to the present level for one or two decades, if ever. Furthermore, the percentage of college age students actually enrolled in college is declining. The bulk of this decline is among middle class white males. The rising cost of education has made it relatively more attractive to poor students, who can get financial aid, and well-to-do students, who can afford to pay, but relatively less attractive to middle class students, who cannot get financial aid and who have difficulty in paying.

The prospect then is for a decreasing percentage of students interested in and prepared for traditional engineering programs, out of a decreasing percentage interested in going to college, out of a decreasing total number of persons of college age.

The evidence shows that more, not fewer, engineers will be needed in the years ahead, although it is not clear how many of them will be graduates of engineering colleges. Certainly, the present job market is very strong and many new jobs should be created by the nation's attempts to solve such problems as energy and the environment. The growth trend in service industries should also create new jobs if engineering colleges are prepared to provide the kinds of graduates needed. Particularly promising are the new areas where engineering interfaces with other disciplines such as law, medicine, business, social science, etc. Attempts at rebuilding enrollments need not be self-serving but can be motivated by genuine desires to provide technically educated manpower to satisfy society's needs.

There are, fortunately, some nontraditional sources from which engineering students can be attracted. Ethnic minorities comprise 14.4% of the U.S. population but only 2.8% of all engineers. It is estimated that 5.1% of engineering freshmen in 1973 were from these minorities, so some progress is being made. The largest untapped reserve, however, is women. Women have traditionally comprised only one percent of the engineering profession and of the engineering student bodies. This number is rising sharply but is nowhere near the 40 to 50% of all engineering students that women optimally could comprise were aptitude for engineering the main limiting factor.

In the long run, however, adding some minority and women students to replace the loss in white male students will not suffice. More fundamental changes are needed in engineering degree programs and employment patterns to attract a broader class of students--male and female, minority and majority. Many students today have different aspirations, attitudes, perspectives, and goals than students in the past and these will continue to be present in the future. To attract students of the quality and in the quantity we need over the next 20 to 30 years will require changes in our engineering programs to appeal to this broader range of students.

2. Instruction

Engineering educational institutions, to a large extent, are what their faculty want them to be. We should, therefore, carefully examine faculty and their role in engineering education. It is generally accepted that the fundamental and foremost role of faculty is to teach. Yet, developments of the past 30 years bring this into serious question, particularly in some of the large research oriented universities.

Certainly the role of a faculty member may be a varied one. Depending on the institution, he may be expected to develop new courses, programs, and curricula; to recruit, counsel, and advise students; to establish policy and administrate programs at departmental, college and university level; to perform public service or consulting; and conduct research and supervise junior researchers while remaining an effective, vital teacher who generates his fair share of student credit hours. In view of this intense competition for his time, it is not surprising that teaching loads, measured by credit hours, or student credit hours, have gone down at large research oriented universities. Neither is it surprising that state legislators, believing teaching is what they are paying for, are attempting to mandate minimum teaching loads at many public institutions.

Not all institutions are the same, of course. At two-year colleges and four-year colleges with minimal graduate programs, classroom and laboratory teaching are the central function of the faculty. At larger institutions with significant graduate programs, where most undergraduate engineering students are educated, much less faculty time is devoted to classroom and laboratory teaching. Research and other duties may take 50% or more of the professor's time. Part of research, particularly that part devoted to doctoral students, does serve a teaching function, but it is reasonable to say that part does not. In addition, the complexity of larger institutions tends to demand more faculty effort in policy and administrative functions.

The growth of faculty research effort has resulted directly from the large amount of federal funding available. The impact of big-time sponsored research on engineering education is much greater than the faculty time devoted to research would indicate. Research supports graduate students, as well as faculty. Further, research overhead is a significant source for support of service centers, such as libraries and computing centers. In many institutions, graduate programs and research have become so dominant that the faculty reward system reflects little else.

The above practices have moved into smaller institutions. In the effort to upgrade faculty, the Ph.D. has become a virtual requirement; however, most Ph.D.s are graduates of only a few prestigiou . institutions which emphasize research and graduate programs. When these Ph.D.s become faculty members of smaller institutions, they choose, or are urged to seek, prestige through the research route. The result is more emphasis on graduate programs and research at the smaller institutions whether the situation warrants it or not.

Critics argue that, while research and graduate programs are important, they should not be emphasized to the point that teaching and undergraduate programs are neglected. A return swing of this pendulum does, in fact, seem to be developing. Interest in teaching methods and techniques, particularly at the undergraduate level, has burgeoned. Self paced, programmed, and computer-assisted instruction; imaginative use of live TV, tapes, and other educational technology; freer use of seminar, discussion, and other interactive modes of instruction; and a host of other methods are receiving major attention, although they have not yet made a major impact on how teaching is done at most institutions.

Interest in design and project-oriented instruction is also growing. Many believe that science-research oriented instruction, wherein the faculty tend to reproduce themselves in their students, is not the best for every student, especially not for those who will work in industry in nonresearch environments. New project design courses have emerged at many institutions and in a few places, such as Illinois Institutue of Technology and Worcester Polytechnic Institute, entire engineering curricula have been designed on a project basis. Efforts to involve industry directly in instruction as well as co-op and industrial internship programs are growing. We may expect increasing faculty efforts in these and other industry related activities.

There is a growing concern that the research Ph.D. without industrial experience is not an ideal background for all faculty. Industrial experience is being reintroduced as a qualification for new faculty in some engineering colleges. Present faculty are being encouraged to gain experience through industrial sabbaticals or leaves, and practitioners are being hired as adjunct or part-time faculty.

Whatever the focus of the faculty, the enrollment decline has affected instruction. Student faculty ratios are down noticeably. A few engineering colleges have closed; others are receiving close scrutiny, with the possibility of closing being very real; some have drastically reordered their programs in attempts to insure their survival, while essentially all have reduced hiring and toughened promotion and tenure requirements. Current engineering faculties tend to be highly tenured and growing older. Effects of this on instruction are not yet clear, but many are worried that needed reforms will be more difficult to accomplish. Looming on the horizon is faculty unionization which promises to have profound far-reaching effects.

Science areas which produce a large number of working engineers have also experienced enrollment declines although not as sharply as engineering. Engineering technology has had the brightest prospects, with general growth in numbers of programs and students. Engineering faculty in some schools share in engineering technology instruction and have therefore benefited. However, the typical instructor in engineering technology lacks a Ph.D. and has come to teaching from industry. In short, in general, he differs from his colleague in the traditional engineering school. For this and other reasons, communication between faculty of engineering programs and those involved in engineering technology programs has been poor.

3. Programs and Curricula

The period following World War II was characterized by the almost universal acceptance of the science-math based engineering degree program. The curricula that had developed by the late 1960's were more scientific than empirical, more content than process-oriented, more theoretical than practical, more analytical than experimental, more specialized than general, with emphasis on analysis rather than synthesis or design, and on basic rather than applied research.

The development of engineering education during this period converged in other ways. Engineering degree programs were developed in a small number of disciplines (civil, mechanical, electrical, etc., and usually in a one-to-one correspondence with a department) and were much alike from one institution to another. Courses with virtually the same content were arranged in the same sequence and were taught by the same techniques. A student in a given discipline did much the same thing in the same way in one institution as his contemporary in another institution.

Aiding this convergence was the wide acceptance by engineering educators of the ECPD criteria for accreditation. By 1973, there were about 280 engineering colleges of which 225 offered ECPD accredited programs at the baccalaureate level. Many of those not accredited aspired to be and had designed their programs accordingly. ECPD also encouraged the upgrading of faculty by hiring only Ph.D.'s and, as mentioned above, since most Ph.D.'s are graduates of a few research oriented unversities, a further contribution to uniformity was made.

During the postwar period, credit hour requirements for baccalaureate degrees in engineering were reduced. Several schools which had adopted five-year baccalaureate programs abandoned them and many schools brought the number of required credit hours more in line with those in the liberal arts. Reasons included putting engineering into a better competitive position with science programs and permitting more effort to be devoted to graduate programs. In reducing the credit hours, however, something had to give, and generally, it was application, while theory was retained.

Unnoticed by most engineering educators, a gap was created in the supply of technical manpower by narrowing the role of engineering education to include only science-math based programs. Into this gap moved community colleges, technical institutes, and some four-year institutions with two- and four-year programs leading to associate and baccalaureate degrees in engineering technology and industrial technology. Industry, hiring according to its needs, filled many jobs formerly filled by engineering graduates with graduates from these programs.

Engineering technology and industrial technology programs have grown up largely independent of, perhaps in spite of, engineering colleges, although there are notable exceptions. More recently, some engineering colleges have embraced engineering technology for reasons ranging from well-thought-out plans to reintegrate the profession to desperate moves to increase enrollment by any means. Other engineering colleges have spurned the movement as beneath their dignity. ECPD has embraced engineering technology by offering to accredit programs although by different criteria than engineering. Industrial technology programs are accredited by a totally separate organization and seem likely to stay outside the scope of most engineering colleges.

A more recent movement to broaden traditional engineering programs has been the development of interdisciplinary degree programs which often interface with areas not normally associated with engineering. These programs permit students to cross departmental boundaries selecting courses from any department that meet predetermined but individualized career objectives. An engineering student may combine discipline areas in engineering, prepare for graduate work in medicine, law, or business, or combine political science, economics, or psychology with engineering. Some of the most exciting work is occurring at the masters level where nonengineering undergraduates are participating in engineering programs or where undergraduate engineers and nonengineers are studying public or social systems together for degree programs in policy or planning.

The success of such programs has influenced more traditional discipline oriented programs to increase flexibility. Long course sequences with interlocking prerequisites have been shortened. Options and free electives have replaced some required courses. New teaching techniques, course organizations, and grading systems introduced flexibility even where course requirements have remained rigid.

Just as interdisciplinary efforts and moves toward more flexibility are picking up speed, ECPD has stepped in with its plan for advanced level accreditation. The criteria for advanced level accreditation extend to five-year programs much the same definition of engineering that now applies to four-year programs. Concerned about overemphasis on analysis at the expense of design, ECPD has chosen to strengthen the design requirement somewhat but otherwise the criteria are very much the same. Many schools, now alert to the narrowness and uniformity resulting from widespread acceptance of the four-year criteria, oppose advanced level accreditation. They argue that it is at best unnecessary and at worst harmful because it would tend to stifle attempts of engineering to respond to rapidly changing societal needs. The issue is whether some of the most exciting technically based programs developing in engineering colleges will remain in or be forced outside the scope of ECPD-defined engineering education.

Another trend toward breaking the lockstep of uniformity in engineering is the continued growth of co-op programs and the evolution of new programs requiring industrial internships and other forms of industry-college interaction. Students, perhaps more than the professors, have appreciated the need for a closer integration of education with practice and have supported these programs enthusiastically. New avenues of industry-college interaction are being sought.

4. Cost and Finance

Engineering colleges have generally shared in the unprecedented growth of public and private support of higher education. Historically public institutions have been supported to a large extent by various levels of government with private institutions depending more upon endowment income, gifts, and tuition. The distinction is not absolute since both types of institutions receive their income from many sources. By 1970, higher education costs had reached 2.48% of the GNP but signs of reluctance to support educational issues have appeared and the public seems unwilling to increase its support for higher education. At the federal level, research funding is shifting from basic and defense related to applied and civilian related. The consequences of this shift to university funding are not clear. Furthermore, the federal government is shifting aid from the institution to the student--a move which should increase the effect of federal aid on private institutions relative to public institutions because of tuition differentials. Other forms of public aid to private schools are being considered. The result is that distinctions between public and private schools according to funding sources may become even more blurred.

The Carnegie Commission has shown that many educational institutions are in a precarious financial position and that nearly all face a period of belt tightening. Control and reduction of costs has become essential but the track record is not encouraging. In the period from 1930-60, increases in higher education costs have exceeded the general rate of inflation by 2.5% annually. Either productivity must be increased, or peripheral costs must be reduced.

Engineering colleges are especially vulnerable to cost reduction. The decline in engineering enrollments has not been accompanied by a corresponding decrease in faculty, so student/faculty ratios have tended to decrease. A continuing problem for engineering colleges is the higher cost of teaching engineering when compared to liberal arts, teacher education, etc. In some institutions, of course, engineering is a money-maker because of research overhead. However, in general, the cost differential makes engineering programs vulnerable to cuts, especially when enrollments are depressed. Several institutions have dropped their engineering programs and others are considering it. A workable method of reducing the cost of engineering education to a figure comparable to other disciplines would increase its appeal to administrations and governing boards.

5. Professional Opportunities for Graduates

Starting about 1968, after years of unrelieved demand for engineering graduates, an economic recession, combined with major changes in defense and space funding, dislocated engineering employment. During the crisis of 1970-71, the unemployment for engineers rose to 2.9%, up from 0.7% in 1968 but still well below the 5.9% for the civilian labor force as a whole. The unemployment was largely concentrated in a few geographic centers; however, the public thought it was widespread. We now know that engineering unemployment was a transient with a time constant shorter than it takes to train a new engineer, although at the time many believed the market would take years to be righted.

This undoubtedly contributed to the decline in engineering enrollments, which will result in sharply reduced graduating classes in the next few years. Adding four-year engineering technology graduates and science graduates will not make up the difference. As a result, a real shortage of engineers is predicted. It is not yet clear whether this will trigger substantially increased enrollments. It is clear that day-to-day needs for engineers are not a reliable guide for students in making career choices.

Opportunities for engineers in new types of technical positions are also likely to expand. Positions in environmental, safety, planning, and regulatory areas are developing. The growth of service industries will create new engineering positions. Prospects for engineering employment are excellent, both in traditional areas and in a host of newly developing areas.

B. Outside Schools of Engineering

1. Students

We are concerned here with persons outside the traditional 18-22 year age group found in regular academic programs in colleges and universities. One group of these persons in need of further education, work full time as engineers or in areas related to engineering and may or may not have a college degree. Their needs as students may be in technical areas, in business and management, or in personal development. We have little data on the characteristics of students and potential students in this group as distinct from the population of engineers from which they are drawn. We can only look at the whole population and make inferences.

The Department of Labor identifies about 1.2 million employed engineers in the United States. This compares with under a quarter million full time equivalent students enrolled in engineering colleges today. Only 60% of the total have their highest degree in engineering and 38% have less than a bachelor's degree. Under 16% have graduate degrees and about 30% are registered as professional engineers in one or more states.

About 50% are employed in the manufacturing aspect of engineering, while 31% are in private nonmanufacturing, 14% in government, and 4% in colleges and universities. The percentage of engineers in manufacturing is expected to decrease, while that in private nonmanufacturing and in government is expected to increase. These shifts result in part from societal shifts from production dominance to service dominance, and in part from the increased need for engineers to participate in the governmental regulation of industry.

In our degree-conscious society, we might expect that those who do not have degrees may seek them; those who have degrees, but not in engineering, may seek to fill in gaps; those with only baccalaureate degrees may seek graduate degrees. Thus, there appears to be fertile ground for the development of continuing education programs by engineering colleges. There may also be an opportunity for a wide variety of nondegree programs.

These engineers are, of course, widely dispersed geographically. Many live and work near an engineering college while others do not. Those that do live near an engineering college may or may not have needs that institutions can fill. In any given locality, the concentration of engineers may or may not be sufficient to support traditional educational programs. In short, continuing education is not just a matter of enrollment in the nearest engineering college. Innovative approaches will be needed if a substantial number of these students are to be reached with a lifetime of continuing educational opportunities.

A second group of students are those who have delayed entry into college, who have dropped out of college and seek to return, or who seek major career changes after the traditional college age. There is growing interest in this group, although its characteristics are even harder to define than the first group. In any case, we may expect programs and curricula to develop in many fields and it would be wise for us to consider engineering programs as well.

2. Instruction

To the extent that regular faculty of engineering colleges offer regular courses for credit to practicing engineers, the comments in Section A apply. A significant instructional development is the live TV class with two-way audio sent to practicing engineers in remote locations. Stanford, SMU, and Michigan, among others, have developed such TV networks. An extension of this approach, using TV tapes and local tutors, is likely to grow. A further extension using a multi media approach is also likely to be significant in the future. The possibilities here seem limitless.

3. Programs and Curricula

Engineering colleges generally encourage practicing engineers to enroll in their regular program and course offerings. In some cases, the employer permits them to attend regular day classes. Engineering colleges will often schedule evening or early morning classes to accommodate employed engineers and when enrollments are large enough will schedule special sections at a time and place convenient for the engineers. The live TV class where the remote engineer is mixed electronically with the on-campus student, has added flexibility. In most of these cases, the course is little different than the on-campus course and the engineer is treated little differently than the on-campus student. Extension courses primarily populated by practicing engineers, do take on a different and broader perspective more related to real-life engineering situations.

Engineering colleges have also prepared special formal non-credit courses, often as short courses. These are usually offered at the engineering college but may be exported to the place of work when enrollments permit it. The new continuing education unit (CEU) is a way to recognize these efforts and some schools (Wisconsin, University of Michigan--Dearborn) are offering a degree based on the accumulation of these units.

These efforts by the schools are, by themselves, insufficient, and as a result, a multitude of additional educational opportunities are appearing for the practicing engineer. A growing effort is the industry based course. Such courses often start as a weekly seminar for a working group of engineers. As the material develops and becomes codified, it becomes possible to offer a more formal course. Such courses have the advantages that topics can be discussed in the context of a particular company, proprietary information can be used, and the contents can have immediate relevance. In many companies, particularly those with rapidly changing missions, we should expect such efforts to grow.

A related development has followed the discovery that material prepared for in-house use can, in some cases, have a much wider appeal with suitable modification. This ha led a number of companies to market courses to the general engineering public in competition with engineering colleges. The videotaped semiconductor courses offered by Texas Instruments are an example. This movement seems bound to grow and profoundly affect the role of engineering colleges.

Professional societies also contribute to the continuing education of the practicing engineer. Their primary mode is through a publication program and sponsorship of technical conferences. More recently, some societies, such as IEEE, have moved into sponsoring short courses, lecture series, and workshops.

The publishing industry for years has produced material for self study. In addition, correspondence schools have prepared material in some engineering areas. Preparing material especially suitable for self study may be a growing business.

So far, most of our comments have referred to technical courses directly related to professional development. Personal development may loom larger for the practicing engineer as his professional career develops and as our society matures. Formal courses in the humanities and social sciences certainly serve this function, but most engineers seek personal development instruction outside the credit course format. Personal development organizations are growing in popularity; hobbies, clubs, and religious organizations offer opportunities for personal development, as do libraries, TV, radio, and newspapers. We may reasonably expect to see more attention paid to this, both informally and formally. Institutions of higher learning will do well to take note of this trend.

Efforts toward continuing engineering education may be described as spotty and haphazard when viewed on a national or regional basis. No systematic plan has evolved, rather each engineering college has proceeded largely on its own, when it has proceeded, and each employer has developed his own plan, when he has a plan. It would appear that many European countries have faced the problem with more organization and foresight. England has its Open University; France has recognized a national obligation to continue the education of French workers and has taken steps to implement it; and Germany has a far-reaching plan in force (see Appendix 2).

Recent developments, largely in the form of reports and recommendations, support a nation plan in the United States for continuing a recurrent education. The Carnegie Commission has strongly recommended shortening the initial college experience, while broadening the opportunities throughout later life. Several other studies strongly support various forms of mind-career retaining. We must conclude from the convincing arguments supporting these recommendations that recurrent education will be a force to deal with in the future. Engineering education, in particular, has much to gain in this direction (see Appendix 2).

4. Cost and Finance

The cost of educational efforts outside of the schools and the means to finance them here are so diverse that good data on them are hard to come by. Many companies, particularly large, high technology corporations, provide continuing education at company expense and often on company time. These companies provide tuition reimbursement for job-related credit courses and appear to be stretching the concept to a broad range of topics, justifying the job relatedness by the unity of professional and personal development.

Some cost data are available and are discussed in Chapter 8. Let it suffice to say here that it is a multi-million dollar operation and the resources to pay for it are readily available in industry. Entrepreneurs will undoubtedly be attracted in growing numbers. Why not the universities and colleges?

5. Professional Opportunities

Most companies reward job performance more than they do continuing education efforts. Some companies have policies that reward the taking of a degree by a salary increase. However, credit courses without a degree objective and noncredit courses rarely receive direct reward. Yet, engineers are generally enthusiastic about continuing education. Some of this is merely the desire for intellectual stimulation. Another benefit may be the insurance against a technical obsolescence that is so severe it may result in job loss. Continuing education may also improve job mobility if the engineer wishes to or is required to change employers. We anticipate that obsolescence, mobility, career change, and personal development motivations will loom even larger in the years ahead, and therefore continuing education will continue to grow.

Chapter 2

THE FUTURE CONTEXT FOR ENGINEERING EDUCATION

Chapter 1 of this report traced present trends in engineering education. This chapter conjectures upon the future. A number of forces which will affect the future can be recognized now. We examine them here as a backdrop for Chapter 3, which contains our specific suggestions for engineering education in the future. We will concern ourselves with those factors which most concern engineering education, speak only of the near future (until the year 2000), and discuss first society, next institutional concerns, then the engineering profession, and finally the individual who will be involved in engineering education.

A. Society

World population will continue to grow, especially in those nations with the least developed technology. This growth will place extreme pressure on food supplies. Further imbalance between population growth and food production will result in famine in some parts of the world and new concepts in sharing everywhere. In the U.S and some other developed nations, the birth rate seems to be stabilizing at a rate which will result in zero population growth. This enviable position will produce strains, but also opportunities, when dealing with other nations.

In this country, our high standard of living has been due in part to high technology which requires a large amount of energy and a lavish use of natural resources. As other industrial nations approach our level of technical development, their needs for energy and raw materials will increase even faster than our own, straining even more the earth's unevenly distributed and politically controlled resources. Both the availability and cost of such resources will be substantially revised. Conservation of energy and resources will become increasingly important. As nations reach a high state of technological development and acquire the corresponding material goods, new concerns with the quality of life may emerge. More attention will be directed toward preserving the natural environment. Aesthetic and visual concerns will increase as cultural sophistication increases. As people become increasingly concerned with the quality of life, they will also pay more attention to their work conditions. Repetitive work will be increasingly attacked as dehumanizing.

Automation will increase, even with a leveling of energy, thereby shifting still more workers into the service sector and at the same time reducing the work week. By as early as 1980, 60% of the work force will be engaged in services, 35% in industry, and 5% in agriculture. People will be more concerned with using their increased leisure to enhance the quality and meaningfulness of their lives. For many, this will involve additional learning, often throughout their entire life span. For the most part, this additional learning will be in limited modules or on a part-time basis and will therefore not fit the present definition for formal schooling. Some of the learning will be for professional improvement and vitality, other will be to meet some perceived individual need or merely for recreation.

Technology will make possible greatly increased communication and information storage capability. This could cause greatly increased cooperation and interaction or conflicts of interest at both national and international levels. Changes in transportation and housing patterns will emerge as nations become more urbanized and meet increasing problems associated with dense social groups.

Society will accept living with growing technology. It will realize that it can live more comfortably and more completely if it is more technologically aware and if technologists and their managers are required/allowed to respond more effectively to society's signals. This means that all persons will come to realize that they must have a better understanding of technology. Exposure to technology will therefore become a fundamental part of everyone's education.

B. The Institution

In order to survive in the future, present institutions face significant changes. Within institutions involved with engineering education, changes will be forced by students demanding a more meaningful learning experience, by industry anxious for a more productive employee, and by society expecting more responsibility and accountability for its investment.

Many schools have evolved over a period of several decades, often a century or more, without discernable plans. These schools embrace a multitude of instructional units, each with its own hierarchy and vested interests. Yet, within these units is an unfortunate lack of diversity, paralleling the lack of diversity among institutions. Schools must minimize the lockstep fostered by rigid and unyielding departmental and college structures. Institutions must be willing to listen with a sympathetic ear to the messages from student, industry, and society and to respond with skill and willingness. Curricula must be tailored to the qualifications of matriculating students. Schools may be required to relinquish some old and cherished concepts and to embrace new and, perhaps, even high-risk concepts, in order to survive.

Schools must reexamine their total mission, including funds and talent devoted to efforts such as housing, feeding, and entertainment. School administrations must engage in critical self-examination in order to determine whether their own hierarchies really serve the institution's mission. As schools have grown or aged, their service elements such as registration, admission, graduate school administration, and libraries have also grown and become entrenched. These service elements must be realigned so as not to hinder the fundamental teaching-learning-research priority of faculty and students.

Even if schools respond in the most favorable manner, they will be threatened in the future by a multitude of new learning delivery systems. Some of these systems will take the form of schools, but without the fetters of tradition, vested interests, or multiple missions. Some systems will appear in industrial plants, others will be community based. For many people, the availability of programmed texts and broad-band communication will offer viable alternatives in learning style.

Schools will continue to be faced with fiscal problems. In the future these problems will be more severe than in the past. Schools must learn to police their investments and operating costs in both personnel and physical plant.

Authors such as Terman* strongly recommend eliminating engineering programs that are not large enough to be economically efficient. He has defined the critical size as a school that graduates at least 125-150 students per year with 3 or 4 major curriculums with each graduating 40-50 BS students per year.

The new directions recommended in Chapter 3 provide a rationale for funding new students and thereby broadening the financial base to retain vigor in our engineering schools.

Society will also demand accountability and responsibility from production industries. These demands will require an increased engineering effort. Manufacturers will be expected to assess the impact of their efforts. Pollution, safety, resource depletion, serviceability, reliability, and longevity are only a few of the new concerns and responsibilities for industry. New monitoring and enforcement institutions, staffed by technically educated persons, will emerge at all levels of government.

Industry will change not only what its engineers must do but what it does with engineers. Industry has tended to use people, and their knowledge, as if they were nonrenewable resources, when, in fact, they represent a continually renewable resource. Just as Weyerhauser replants forests, industry must come to believe in replanting knowledge. Thus, it must assume a major role in the continuing education of engineers.

C. The Profession

The engineering profession must redeem itself in the future. In general, it has not yet accepted its new dimension, including the fringe areas and those attacking societal problems. It must broaden its scope

*F. E. Terman, "Engineering Education in New York," State Education Department, The University of the State of New York, Albany, N.Y., March 1969.

to include a myriad of new members, including technologists. The profession will need fewer engineering scientists, but this decline will be more than compensated for by an increased demand for applications, production, and design engineers from both engineering and engineering technology programs.

The engineering profession must resist erosion by competing groups in technology, science, and planning. This resistance can best be evidenced by an outward turning instead of an inward turning. This outward turning includes embracing emerging disciplines, such as in environmental, urban, and health areas, having a technological base. It includes a reunion with technology on one hand and a continued union with applied science on the other. As the profession broadens its areas of concern, it must reunite educators and practitioners.

The profession must set standards for itself and then aspire to those standards. This move should reflect renewed concern for education, not just certification. It needs to resurrect its emphasis on the individual engineer rather than on in-house engineering staffs. Failure to do so will degrade engineering to a "support" discipline, incapable of self direction. Some signs of failure in the form of increased unionization, industry's wide use of "engineer" in job descriptions, governmental attitudes, and declining engineering enrollments have already appeared. Some of the responsibility rests with the schools, some with professional societies, some with accrediting agencies and with state licensing boards. The fact that most industry ignores licensing requirements contributes to the decline of the status of the engineer as a practicing professional.

The engineering profession can find its strength in its diversity since by this diversity it enters not only the mainstream but the tributaries of society. Unfortunately, this diversity is also a fragmentation, whereby the profession must guard against becoming unable to speak forcibly on any subject at all. The profession must develop a conscience. It and its members must learn to articulate social, political, economic, and environmental concerns based upon technological competency. Difficult as this may be, it may sometimes entail assuming an adversary role with the management/financial sector.

Society will demand accountability and responsibility from all its decision makers. The profession must learn to respond to these demands without undue hazard to its many members.

D. The Individual

Of central concern to engineering education is the individual who will study and later practice engineering. It is important that engineering colleges retain the traditional student--an achieving person who followed the college preparatory course in high school, who is goal oriented, and who may be pursuing engineering as a means to financial gain and upward social mobility. This student will be welcomed as a valuable input, but we are concerned that cognizance be taken of a variety of other potential students.

Many entering engineering students will submit nontraditional credentials for entrance, since secondary schools today provide a much wider spectrum of learning experiences. Granted that factual content and job preparation are primary goals of many students, an increasing number will search for unique and personal ways to become technologists. Some of this group will be impressed with engineering as a vehicle for meeting social needs. They will seek out collateral learning which supports their impression. Others, holding fast to engineering as a means to economic or social goals, will nevertheless wish their institutionalized learning to lead to an enhancement of their lives.

As students look at industrial demands and their own aspirations, some will choose engineering technology programs, some will choose traditional engineering programs, and others will turn toward science and mathematics. Still others will seek areas emerging at the boundaries of engineering with political science, psychology, and many other fields.

The engineer of the future should recapture his engineering heritage as a problem solver, seeking particularly open-ended or probabilistic solutions as they are affected by social, political, and economic factors. To an increasing extent, he should enter the public arena to sell his solutions by the political process. For this, he must be prepared to deal with people in ways not common for most contemporary engineers.

The analysis and computation based engineering science curriculum will be preserved, but there will be a return to greater emphasis on design and synthesis, particularly at graduate levels. Engineering educators must include not only those skilled in analysis and synthesis, but also those able to distinguish value and appropriateness of engineering solutions as solutions to social problems.

As we approach a steady state society, the engineering graduate may no longer be able to hold unlimited professional mobility as a realistic goal. More engineering graduates can expect to remain engineers during their entire careers unless specific preparation is made for career change. For this kind of person, a broader educational base must be offered upon which to build later learning. Opportunities for delayed training must be provided to enhance his technical vitality, an asset both to himself and to his employer. Of fundamental importance will be learning experiences in which he can pursue personal development without regard to his professional competency. These learning experiences will encourage some engineers to seek a series of careers, others to become more productive in their jobs, and others simply to become more self-realized.

Chapter 3

ENGINEERING EDUCATION FOR THE FUTURE

The last two chapters have discussed present trends in engineering education and the future as it may affect engineering education. This chapter will present recommendations, some specific and some general, which we feel are necessary if engineering education is to remain a vital and effective force in society. The recommendations which we make in this chapter are compatible with present trends and constraints and can conceivably be put into widespread practice in the near future (1980-90). Many of them are already in effect in a few schools. They have proven workable and await only the overcoming of the barriers discussed in Part II of this report for widespread adoption.

In our study, we concluded that there were presently two general shortcomings in engineering education. The first is that engineering education, as traditionally defined, occupies a much too narrow role in the total spectrum of technically oriented education needed by today's and tomorrow's society. The rigorous, science-based programs characteristic of the past quarter century [1] must be augmented to take account of social changes, changes of the engineer's role in society, changes in individual values, and newly emerging national concerns such as energy and resource conservation, environmental quality, urban design, and other problems interfacing technology and society [2].

The engineer's education must emphasize affective as well as cognitive skills, methodology and process as well as content, specialization not at the expense of generalization, and analysis in the context of synthesis. Above all, it must be one which produces engineers able to work with others in complex and controversial situations, engineers imbued with a sense of national concern and social responsibility, not only as human beings but also as engineers engaged in problem-solving [3].

The most pressing present need is to lift and broaden the horizons of engineering curricula and of the engineering educators responsible for the design and implementation of these curricula [4]. The second shortcoming has to do with the nature of the educational process itself. We feel that society and technology change so fast, the educational problem is so complex, and the need is so great, that engineering degree programs that prepare a student for career entry can only do a part of the job. We see, therefore, the need for a much greater emphasis on the continuing education of the engineer as a professional and as a person after career entry. Appendix 2 makes this argument in detail.

Traditional engineering education has been viewed as providing a set of unique skills which will be useful throughout a person's lifetime. Now, with engineering practice being largely omitted in the schools, and with the educational emphasis on analysis, both because of the shift toward science and because theory is considered longer-lasting than practice, engineers do not become competent professionals until they have practiced engineering for several years after graduation. Thus, already, the early years of an engineering career are integral parts of engineering education. As one becomes mature in a professional career, one not only must possess technical competence, but also feel vital as an individual, be able to work with others, and be able to communicate and persuade. One must be secure in one's impression of personal importance and know that one is in fact contributing to self, family, community, and mankind. Thus, humanistic and social concerns become increasingly important to the professional engineer and may eventually rival or dominate technical ones in determining educational needs.

We feel that in order to rationally design the portions of an education, education must be considered as a lifetime totality and emphasis placed upon learning in a recurrent mode. Technology does not stay fixed. Neither does the typical engineer. Even if the knowledge he learned in school remained current, he might grow beyond its application. He must be prepared to encounter job changes, new fields, new problems and priorities, shifts toward management, changing family involvement, changes in personal philosophy, and even major career dislocations. All of these speak in favor of recurrent educational opportunities.

The recommendations which follow address engineering education both before and after career entry. Most of them have been made before. However, in our opinion they have not been put into practice and are crucial. We feel that they remain in the talking stage because of various deep-seated barriers that exist, mainly in the educational institutions. Part II of this report, which follows this chapter, contains detailed discussions of some of these barriers and specific recommendations as to how they can perhaps be overcome.

A. Before Career Entry

1. Variety of Options

a. Science-Math Based Programs

Our present engineering programs are and shall remain the heart of our educational effort. These programs have grown over the years in response to clearly felt needs and the graduates are highly valued by employers. The high technology industries will continue to be a major employer of engineers and the demand for science-research oriented graduates will continue strong. We should do nothing to inhibit this kind of program or the number of graduates.

We believe, however, that we must add to our present range of programs. The needs of students, the profession, and society suggest that new programs and program structures are desirable for at least a part of the output of engineers in the years ahead. Not to move into these new directions would limit the scope of the profession and could very well result in smaller, less vigorous engineering schools in the years ahead.

b. Design-Synthesis Systems

There is a growing interest in design which should be encouraged. This is not a new element in engineering education but one that lost ground in the past three decades in the swing to increased emphasis on analysis. Now, for a variety of reasons, not the least of which are student interest, demand, and response, design is again assuming its rightful place in the engineering curriculum [5]. The theme that this should occur in close cooperation with industry is developed in later sections of this report.

It should be noted that design-synthesis material that can be introduced has been much enhanced by the introduction of the system's approach to problem solving using various techniques of engineering analysis, simulation, and optimization. In such a developing field, new experimental programs should be tried as alternatives to present traditional engineering programs.

c. Combined Programs

In order to maintain ties with and yet break out of traditional molds, some schools, such as UC Berkeley and Michigan, encourage combined degree programs [6]. We recommend much wider availability and use of these opportunities. Thus, a student interested in some phase of biomedical engineering might combine, say, microbiology and electrical engineering. The student would receive two baccalaureate degrees, each according to traditional requirements for that degree, in about five years of study. The value received, however, may be greater than the sum of the two. Since such programs involve courses already in existence, the educator's main task is to make the system work freely and flexibly to the student's benefit with an absolute minimum of academic and bureaucratic exigencies trammeling the education path.

Another valuable form of the combined degree is the 3.2 program wherein the student spends three years at one institution, usually a liberal arts college, followed by two years at an engineering college. Baccalaureate degrees are then awarded by each institution.

Still another form is obtained by taking a baccalaureate in one field and a master's degree in another. In some cases, the master's degree can be earned in the minimum one year and sometimes it takes longer but rarely more than two years.

All these forms are recommended because they provide opportunity and diversity for the student without major conflict with traditional program offerings.

d. Individually Designed Programs

In any given discipline area, such as mechanical, electrical, civil, etc., engineering curricula look very much alike from one institution to another. Given the small number of recognized disciplines, it follows that the budding engineer's choice of paths through engineering are limited, or would be limited if not for a growing trend toward individually designed programs, such as at Stanford [6,7]. We recommend more institutional support to allow at least some students to design individual programs which may cut across traditional department or college curricular boundaries. Not all engineering students are apt to want this much freedom in selecting their educational pattern. But the means should be made available through increased faculty advising and decreased institutional obstacles.

2. Nontraditional Students

a. Women

Just as many engineering curricula look depressingly alike, so do the social and psychological profiles of traditional engineering students [8]. The number of women attracted to engineering has traditionally been almost vanishingly small [9]. A variety of social forces outside of engineering schools may currently be helping to change this fact. But the engineering schools themselves must take positive steps to see that women are aware of the opportunities available to them through an engineering education.

b. Minorities

Another group which has seldom chosen engineering as an educational target are the minorities [10]. Again, there are social forces at work which are helping to change this. The engineering schools must be careful to nurture these forces. Ongoing positive action is needed to place before minority groups and individuals (early in their formal education) the benefits that an engineering education can offer them in terms of a more fulfilling life.

c. Socially Oriented Students

Many studies have demonstrated that most students of high creative potential do not choose engineering training, or, if they do, that they tend not to stay with it [11]. These drop-outs or transfers, the studies show, are often very bright, complex in outlook, unconventional, tolerant of ambiguity, original and mature. Except for the first named, these are not so often the attributes of those who choose to stay. A variety of reasons are given by the leaving students in support of their decision, the most popular being some variation on the theme that they have been "turned off" by the rigidity of the engineering curriculum. It is important that new curricula, new counseling procedures, and new faculty attitudes be developed to recruit and retain these students in engineering.

d. Late Entrants

In addition to the aforementioned groups of students who do not, by tradition, choose to study engineering, there is another group who are nontraditional in the sense that they do not start out as freshmen in the engineering school. Some of these are people who, after a year or more of some other major, may decide to try to move laterally into an engineering curriculum. Such students often find that their already completed courses are not acceptable for transfer and that they must pass a long list of lower division courses in mathematics, chemistry, and physics before admission to the inner sanctum of upper division engineering curriculum can be granted. For departments increasingly in need of friends (students), this is a most unfriendly procedure. Engineering departments should take a fresh look at this kind of procedure with an eye to making it easier for such transfers to take place.

Finally, more consideration should be given to those students who, for a variety of reasons, start formal engineering education later in life than usual, those who want to go to college on a start-stop basis, stopping out for a semester or a year at a time, as well as those who want to, or must, work full or part-time while attending engineering school. All these kinds of students are traditional in the sense that they seem always to have been with us, however, they are often discouraged by rules, procedures, and attitude which seem to favor the regular, full-time student. More engineering colleges should take more favorable steps to encourage these students.

3. Expanding Boundaries

a. Technology-Engineering-Science

The development of strong science-math based engineering programs was an excellent move; the simultaneous abandonment of applications oriented technical programs was an error on the part of engineering colleges. A number of schools of engineering technology now exist totally outside of the schools of engineering [12]. There is little communication between the faculties of these schools and the traditional engineering schools. The result is a fragmenting of technical education that works to no-one's advantage. The students are prevented from gaining an overall view of engineering and the faculties and administrations spend valuable energy in rationalizing the superiority of their particular type of school. In actual fact, engineering and engineering technology, as presently defined, are part of a spectrum. The engineering technology schools exist partly to fill the void left by the engineering schools as they swung toward science and math. To pretend that one viewpoint is less valid than the other is counterproductive.

We recommend where both schools exist in one institution, they be joined in a single administrative unit. The students and faculty of both schools can mutually benefit.

We do not mean that all institutions must offer a full range of both engineering and engineering technology programs. Some institutions may choose to concentrate on one or the other. But where both exist in one institution, there is more to be gained by a single administration than two competing ones. And when both exist, a way must be found for students and faculty of technology education to exist as first-class citizens, not as poor relations.

Likewise, engineering colleges must retain and strengthen their formal ties with science and mathematics programs. The move to broader involvement by engineering colleges is not a signal to open a gap to be filled by applied scientists and mathematicians.

b. Interface Areas

As the engineering educator begins to think seriously about providing educational modes that can best prepare engineering graduates to operate at the technology and society interface, it becomes increasingly clear that flexibility at both the personal and the institutional level is the key to the future. Provision must be made for engineering students to be able to design programs that can acquire and integrate knowledge from such diverse but related areas as: bio-life-medical sciences, law-public policy-planning, humanities-art-aesthetics, social-political sciences, and business-management. This will not be easy since the flexibility required is inimical to the academic pasttime of building ivory towers and empires.

Combined programs and individually designed programs discussed earlier are steps in this direction, but they are not alone enough. New courses that integrate diverse subjects must be developed. Cross-fertilization and cooperation of faculty, as well as students, must take place. New programs designed from the beginning around a new core of faculty and student interest and expertise must eventually develop. Whole new approaches to academic preparation may evolve [13].

There are also excellent opportunities for research in the interface areas. Research by interdisciplinary teams is receiving increased attention and support. The universities should find ways to encourage this to improve cross-fertilization.

c. Technology for Nonengineers

While engineering educators are expanding the horizons of their own students, they must also think about their responsibility to provide nonengineering students opportunities to better understand and appreciate the methods, impact, and history of technology. The concept of courses and programs for engineers to be educated in areas which interface with traditionally nonengineering subjects must be extended to permit nonengineers to be educated in areas which interface with traditionally engineering subjects. Again, the key is cross fertilization of students and faculty.

Beginning strides have been made recently in this area. The Center for Information on Engineering Programs for Non-Engineers (EPNE) at Lafayette College directed by E. V. Krick serves as a clearinghouse for such information. A series of references to ASEE Journal articles on this subject appears in the bibliography of this report [14].

4. Implementation

a. Career Counseling-Recruiting-Admissions

The number of education and career options open to young people is staggering. Opportunities expand each day, and if the recommendations earlier in this chapter are followed, even within engineering alone, the variety of opportunities will be very great. This puts a premium on good counseling as never before. Unfortunately, time spent by faculty in counseling students is often unrewarded: no released time, no adequate support services, and, worst of all, no prestige because the outcome is not measurable when compared with the academician's stock in trade, research, publication, and teaching. The student-centered activity of counselling must be made at least as important in the institutional reward matrix as research and publication.

As has been stated previously, engineering schools must begin actively to seek out students of both traditional and nontraditional types. A sustained effort must be made to enroll and keep in engineering curricula students from a far broader range of types than has occurred in the past [15]. This effort must extend into primary and secondary education. Lower school counselors have a difficult task that can be aided by colleges of engineering. Programs for counselor training as well as direct contact with the students are necessary.

b. Faculty

That research and publication is an extremely valuable contribution for many faculty members is not questioned. What is questioned is the claim that all faculty in all engineering colleges should excell in basic research. Obviously, we have never even approached such a state but we have approached a state where prestige is largely determined within the engineering education community by research and publication. If our recommendations are to be successful, we need to change our measures to achieve more balance among the rewards received, including prestige, for various faculty activities.

Basic research must give way, in part, to more emphasis on applied research and design and to interdisciplinary research. The variety of options, new kinds of students, and expanding boundaries of instruction will require more attention to teaching and counseling. Ways must be found to measure superior performance in these activities and reward them.

Not all institutions need emphasize the same activities. Some engineering colleges may continue to emphasize basic research, others will choose applied research and design, while others will be concerned more with teaching. We should have a balanced mix of different kinds of institutions and a hierarchy of excellence based not on choice of principal activity but on performance.

The choice of faculty members is critical. In the next 20 years, large numbers of engineering faculty who started in the technical boom during and right after World War II will retire. Thus, the opportunity will exist to find new faculty members. These new faculty must meet new criteria of experience, interest in student development, standards of social consciousness, and personal development, in addition to old criteria of teaching ability and/or technical competence in research and publications output [16].

c. Co-op-Internships-Projects with Industry

Just as industrial experience should play a greater role in the standards of faculty preparation, so should industrial experience play a greater role in the educational process itself. Students should have far greater opportunities for meaningful experiences in the world of work as a part of their formal engineering education. Besides the learning value of direct experience, the improvement of motivation for regular course work plus the chance for career selection and/or exploration are especially important.

Co-op programs are well established at many institutions [17]. Industrial internships are gaining favor as part of the degree requirement, particularly in some graduate programs. Project courses, often in direct cooperation with industry, are multiplying. These efforts should be encouraged as beneficial to the personal and professional development of the student.

Engineering educators may need to enter the world of work to convince managers, superintendents, chief engineers, and policy-makers that cooperation on a broad front benefits them too. This is not self evident to most people in industry. It may call upon the engineering educator's best efforts in tact, resourcefulness, imagination, and flexibility to make it apparent and to make it happen.

d. Matching Teaching to Learning

No educator needs to be told that students respond in different ways to different methods of instruction, nor that different methods of instruction are better, or worse, for certain types of material presented. Appendix 3 of this report provides a useful compendium of some available teaching techniques. Increased attention to the pedagogic problem of the discovery and transfer of knowledge is needed. Attention must be given to ways that allow more interesting, efficient, and meaningful matching of material and method with student by different and optional approaches or techniques [18].

Currently, engineering tends to rely heavily on lecture and laboratory methods. These methods are useful and, in some areas, are the best choice, but they are only narrow bands in an enormously broad spectrum of techniques currently available.

e. Coordination of Institutions

The call for breadth, variety, and diversity would be an impossible demand if each and every institution were expected to follow every path. Many engineering colleges must necessarily assume a specialized role within the limits of their resources and goals. The diversity we seek is in the totality of opportunities available to a student in the nation, in a region, in a state, or in a locality. A sensible, balanced diversity, then, necessarily demands coordination of institutional activities.

Institutions must be aware of the operational diversities and idiosynchrasies of other, related institutions. Students view high schools, community colleges, private and state colleges, and universities as different pieces of a vast apparatus. A student who makes the proper sequence of manipulations and responses will find an opportunity for the kind of education he desires. For this apparatus to work efficiently, from the student's point of view, the pieces must be different. Each piece must offer choice and flexibility, but the pieces must be interconnected in such a way that momentum gained in one part of the apparatus can be effectively transferred to another part. Unfortunately, an individual institution may perceive itself as the entire piece of apparatus and therefore feel little or no need to pay any significant attention to outside influences and occurrences. Steps must be taken to define roles and coordinate efforts.

State-wide liaison committees between engineering colleges and community colleges have been organized in California and other states. State or regional conferences of deans of engineering are sometimes held. ASEE provides a forum for regional and national conferences. These efforts could be expanded and improved to provide more coordination and cooperation, less unnecessary duplication, and more diversity of opportunity for the student.

f. Open Universities-Credit by Examination

Development of open schools and external programs has added a new dimension to higher education. Human beings occur in endless variety and learn in an infinite number of different ways, situations, and places. If the increasing importance of degrees is based on truly justifiable values, then an increasing number of ways must be available to earn degrees. Many schools and some state-wide systems of schools are implementing external degree work.

In addition, many schools are finding that they can, to their own satisfaction, keep adequate institutional standards and still allow ever-increasing opportunities for credit-by-examination or credit for specific experience.

Engineering colleges should share fully in these developments.

5. The New Technical Education

As education has developed from the earliest times, man has gravitated toward the view that the proper study of man is man. The original disciplines of the humanities--philosophy, literature, religion, fine arts, history--sought to describe man's relationship to his universe, but this knowledge was only sparingly applied to better man's condition. The emergence of science and later psychology and the social sciences resulted from the quickening tempo of life and saw the liberal arts becoming more introspective and concerned with effects of their studies.

What we think of today as the liberal arts curriculum in our colleges and universities grew from this beginning. The purpose of the liberal arts curriculum has been defined for us by A. W. Griswold [24].

> "The purpose of liberal education is to expand to the limit the individual's capacity--and desire--for self-improvement, for seeking and finding enjoyment and meaning in everything he does. The purpose of the liberal arts...is to awaken and develop the intellectual and spiritual powers in the individual before he enters upon his chosen career, so that he may bring to the career the greatest possible assets of intelligence, resourcefulness, judgment and character."

This contrasts with traditional engineering education which still attempts to impart a lifetime's necessary technological knowledge as preparation for a professional career. The modern trend toward professional development courses and life-long learning now makes it possible to reconsider the content and purpose of engineering education and suggest that its goals are not substantially different from those of a liberal arts education.

Humanities and social science should be treated as an integral part of the liberal engineering curriculum. The humanities and social sciences help ensure that engineers have a perspective on their lives, the society within which they live and work, and upon its growth and development. They must study people in human situations and understand social systems.

The Olmstead Report [25] emphasized the developmental and contextual roles of humanities and social sciences over the utilitarian and cultural roles. Whether or not one agrees with this emphasis, it is clear that sending engineers to humanities departments for a few randomly selected courses is not adequate. Too often engineering students find that the courses they take in humanities or the social sciences have, in fact, shifted away from any liberal or liberating objectives toward disciplinary objectives which focus on a rigorous presentation of subject matter for their own majors. Such courses are not the best for an out-of-department student who hopes to be introduced to insights and overviews of what it means to be a human being.

Just as the successful integration of science, mathematics, and engineering was the consequence of engineers being actively engaged in the pursuit of mathematics and science, it appears that a successful integration of humanities and social sciences with engineering will require engineers to be engaged in the humanities and social sciences.

Engineering educators must realize that their own attitudes in this area are of tremendous importance. It is significant that the participants in the ASEE Humanities-Social Science Project Workshop held at the University of Virginia in December 1973, said (with reference to the Olmstead report), "The report underestimated the role of engineering faculty member as a significant model for his students to imitate in attitude, in setting priorities among values, and in his own understanding of humanities and social sciences. The spread of an engineer-faculty member's attitudes among his students is noticeable."

B. After Career Entry

1. Continuing Education

a. Professional Development

Courses and programs for the continued professional development of the practicing engineer often are available on a haphazard basis. A greater variety of subjects coupled with more and better delivery modes are needed. Most important, all this material needs to be catalogued, categorized, and advertised so that individual engineers or companies can know what is available and can plan the best way to integrate it into their own plans. These courses and programs in continuing engineering education should have one or more of the following objectives:

(1) Help the practicing engineer improve his competence in his primary field.

(2) Help him gain competence in closely related fields either to broaden his competence or to evolve in new directions.

(3) Help him move to a new field (career change).

(4) Be broadly available geographically.

(5) Be reasonably priced.

Lifetime learning activities should achieve a prestige comparable with pre-career learning by moving from a remedial status to a primary activity in our society.

b. Personal Development

In striving to produce engineers of high technical competence who have the breadth of vision and understanding to care about and deal effectively with the problems of modern society, we must not overlook that the engineer needs to develop in ways that are separate from, though inextricably linked to, his professional life. This kind of personal development is usually carried on in a random fashion with little continuity or coherence. The longing for personal growth, self-fulfillment, and self-development is the capstone of all man's needs and symbolizes his desire to realize the full range of his individual potential as a human being.

This is uncharted territory. In the future, engineers should give more attention to this aspect of their lives. Employers should be willing to give equal status to personal development explorations as they do to increased technical training. This need not be viewed as an entirely charitable act, since there is growing belief that personal development can have professional payoffs.

2. Implementation

a. Job Design and Task Assignment

There are a number of simple yet effective means to promote learning on-the-job. Most corporate level engineering problems must be subdivided many times before a piece of the problem is assigned as the responsibility of an individual engineer. The assignment of an individual engineer to do a specific engineering task should be at least partially guided by the interests of enhanced learning and the long term vitality of the individual and the engineering group [26].

b. Impulse Learning

From time to time, a given engineering task will seem to defy accomplishment. At this point, an impulse of learning that is immediate and specifically pointed to the task must be achieved in order to accomplish the task. The impulse may mean bringing in a technical consultant to tutor the engineers or sending the engineer to visit an expert. The important point is that the company bureaucracy must be able to respond quickly and effectively to allow a timely impulse of learning by the most appropriate means.

c. Lateral Transfers

Professionals learn the most when they first confront a problem in a new area. Device design engineers will undergo rapid and extensive learning if they are transferred to a device production engineering group. Such transfers must be encouraged as a part of the professional development of the engineer. This principle of lateral transfer has been an accepted corporate policy for those who are being groomed for the highest levels of corporate responsibility and should be tried for engineers.

d. Term Advances

Opportunities should be sought for promotions within engineering or out of engineering for specified terms. This will allow more engineers to acquire some managerial experience (i.e., to have a learning experience) and to some extent such a policy will relieve the Peter Principle Syndrome. Some engineering colleges have done this with term appointments for departmental chairmanships and college deanships. It is possible to do this in industry and to do it without social stigma upon return to the ranks.

e. Employer Support for Corporate Related Course

The employer should pay any tuition fees and allow company time for an engineer to enroll in any course that has a clear application to the needs of the corporation. The particular course must be approved by company officials. In many cases, the course will be arranged by company officials, especially for the employee engineers. Expansion of this type of learning opportunity will undoubtedly lead to the establishment of more-or-less formal learning centers within each company, division, or plant. Within the learning centers, the full range of instructional materials will be found, i.e., credit and noncredit multimedia instructional course materials from academic institutions, from non-profit organizations, and from profit making education companies. Through the learning center, an individual engineer will be able to obtain information on resident university and nonuniversity full term and short term courses and programs.

f. Employer Support for Personal Development Courses

The employer should pay the tuition fees up to some reasonable limit for those courses and programs the engineer wants to take for his personal development or as a result of a personal interest. No company time should be available for these pursuits and no carry-over or accumulation of such funds should be allowed. On the other hand, the individual employee should be the sole judge of the desirability of such a particular course or program.

g. Industrial Sabbaticals

The sabbatical policy, with a long history of success in education, should be adapted for the working engineer. If learning is to be a substantial and continued part of an engineer's professional activity, periods of complete withdrawal from day-to-day engineering activity will be necessary in many cases. Problems of reentry remain but they can be surmounted.

C. Recurrent Lifelong Education

The model of education that keeps a student in school for 17 to 21 years and then thrusts him upon the world of work, presumably so full of education that it will last a lifetime, is coming under increasing attack. Continuing education discussed in Section B has developed to make up deficiencies, support career change, fight educational obsolescence, and generally to support personal development. There are critics, however, who do not think this is enough. They believe the whole educational system should be remodeled to provide for recurrent periods of education throughout a person's life. It is contrasted with present practice which puts such a heavy premium on the front end or early years of education and relatively little emphasis on later years.

Recurrent lifelong education is discussed in detail in Appendix 2. We recommend that this mode be considered for future engineering education, either as an alternative to our present system, or, more likely, the evolutionary result of greater emphasis and development of continuing education. For, as continuing engineering education becomes more fully developed and accepted, it must necessarily influence the pattern of engineering education before career entry.

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Part II

INSTITUTIONAL OBSTACLES AND STRATEGIES FOR RESPONSE

In which we identify current obstacles in the way of new directions for engineering education and discuss strategies for overcoming those obstacles.

Chapter 4

FACULTY

The first three chapters of this report were involved with discussing present trends in engineering education, briefly predicting some future trends that would be influential in engineering education, and suggesting future directions which would ensure that engineering education remain a vital force in the profession and in society. Many of these suggestions find surprisingly little disagreement among members of the academic community or others interested in engineering education. However, even though many of them have been around for a while, they do not seem to be put into general practice. We believe that this is due to the existence of obstacles. The following five chapters discuss some of these obstacles and suggest ways of minimizing their influence.

To suggest that faculty are an obstacle may be a disservice. We regard faculty as our greatest resource. Certainly, the last quarter century has seen great improvement in the quality of engineering faculty. The problem, then, is not one of quality. The problem is that engineering needs in the next quarter century will assuredly be different than the last, and the faculty must, as assuredly, be different.

Fortunately, engineering educators have been innovators from the start and have shown flexibility, imagination, and purpose in the evolution of engineering education. This chapter explores ways to speed this process.

A. Match or Mismatch

An obstacle is present when a worker and his mission are mismatched. Engineering faculty today tend to be products of a graduate education system oriented toward theory, discipline, department, scholarship, and research. To the extent that an engineering college has the mission of conducting basic research and similarly oriented graduate programs there is no mismatch and therefore no obstacle. Current faculty are admirably suited to perform these functions.

In the next quarter century, fewer institutions are likely to devote themselves primarily to this mission, and fewer engineering faculty will engage in it. There is a noticeable drift toward applied research in close relationship with industry and to broader, interdisciplinary, team-type research. This produces a mismatch, for few faculty have extensive industrial experience and fewer still the appropriate broad training for interdisciplinary research.

The mismatch is even greater for those engineering colleges that regard undergraduate education as a primary mission. Few new faculty have had systematic preparation for teaching. Furthermore, most engineering students are preparing for employment outside of research. The lack of industrial perspective in faculty is particularly unfortunate if the predicted role of engineering in solving great societal problems does dominate engineering practice in the years ahead.

Furthermore, if engineering education does indeed seek diversity and flexibility, if it moves strongly into new interface areas, the faculty must be more flexible and diverse also.

The situation cries for a closer match between faculty and their mission. To this end, we recommend:

(1) That engineering colleges require their faculty to seek broadening experiences--particularly in industry and government--on a periodic basis.

(2) That the conditions for the hiring of new faculty and the granting of tenure be geared not only to specialized technical competence but also to appropriate broadening experience and to evidence of flexible creative adaptability to changing educational needs.

(3) That greater use be made in teaching, research, graduate committees, and planning and policy functions of part time or adjunct faculty with extensive practical experience.

(4) That new faculty be required to participate in an intensive practicum course in teaching methodology, evaluation techniques, etc. to provide a solid base for entry into teaching and that all continuing faculty be required to participate in short intensive study to update their teaching competence.

(5) That broadening industrial or governmental experience become a formal part of graduate degree programs and that every doctoral program include study to insure that professionals, whether as teachers or practitioners, encounter formal thought and discussion on communication and teaching.

B. A Problem of Allegiance

One result of massive federal funding for research at some engineering educational institutions has been the transfer of allegiance of many faculty from their own institution to the funding agencies which support and the professional societies which recognize and publicize their accomplishments in their professional disciplines. The practice of funding agencies of dealing directly with faculty sharpened this effect. Faculty welcomed this practice for it gave them freedom to pursue their individual research interests. Since grants were often portable, they could change institutional bases easily. The universities welcomed the external funds and the resulting prestige.

The implications of a faculty with a primarily professional rather than institutional focus are profound. What has evolved is a system in which a university houses, supports, and provides security for a faculty who focus much of their energy on extra-institutional goals. Unless the university chooses a mission that is compatible with its faculty's professional goals, it may find difficulty in fulfilling its mission. If it chooses to alter that mission, it may find that faculty allegiance is a major obstacle to change.

To enable a more effective response, we recommend:

(1) That public policy on federal research funding be reexamined to establish new funding arrangements which encourage an environment wherein universities and their faculties can have common goals and objectives. Furthermore, we recommend that federal funding agencies lead in developing such new arrangements.

(2) That, if the system continues to support values which cause faculty to focus on extra-institution goals, the university re-evaluate its position of providing lifelong tenure and consider alternate university-faculty relationships. These may include: (a) positions contracted (tenured) for a specific period of time, (b) positions with partial tenure only for specific university oriented tasks.

(3) That, in an effort to establish some independence from funding agencies, universities seek support through means which do not undermine their ability to meet institutional objectives.

C. The Steady State Faculty

During the period of growth of the last quarter century in engineering education, change occurred easily with the addition of new young faculty. Now that growth has stopped, few young faculty can be added; in fact, many engineering colleges are reducing their faculty. The problem is compounded by the relatively few retirements in the immediate years ahead. Where engineering in the part tended to have a faculty younger than average, it now faces having a faculty older than average and one that is highly tenured.

The frequently heard comments that older tenured faculty are passive and dated are overstatements. Most older faculty remain professionally and personally vital throughout their careers. However, a few do not. Those few who do not can be tolerated in a growing engineering college, but when growth stops, even a few can be a serious obstacle to the vitality of the college. Ways must be found to renew their spirit.

Research and publication is usually touted as the cure-all for lethargic dated faculty. Research is new, it is stimulating; therefore, he who publishes must be vital. This may be, particularly if the research interests coincide with the mission of the institution. Suppose, though, the mission of the institution changes. Research, just any research, may not do the job. Ways must be found to encourage moves into new kinds of research, not always an easy task for a faculty member.

Furthermore, research is not the only revitalizing endeavor. Developing and teaching new courses can also revitalize. Adopting newly available teaching techniques can add a new dimension.

Industrial experience and public service are yet other ways to pump new life into faculty.

Whatever the path to revitalization, performance must be evaluated, and where it is superior, it should be rewarded.

To revitalize faculty, we recommend:

(1) That evaluation of faculty performance be improved and expanded to include: (a) quantitative measures of teaching effectiveness through student, peer, and administrative review, (b) quantitative measures of counseling and other service activities within the university, (c) in addition, to grant and contract dollars awarded and paper published, a measure of the appropriateness and value of research conducted to the institution's mission, (d) a measure of the willingness and effectiveness to develop contacts and obtain experience in industry or government.

(2) That promotion, tenure, and leave policy be altered to encourage superior performance in any or all of the above areas, particularly in those institutions where research and publication is now the primary path to reward, yet the institutional mission is highly tied to undergraduate education.

(3) That short term rewards, such as departmental and college recognition, seed money for innovative ideas, summer appointments, and released time be made greater use of to stimulate superior performance, particularly when faculty move into new areas of interest.

D. Engineering Faculty as University Faculty

Engineering faculty have never enjoyed the full independence or suffered from the isolation of many other professional school faculty. Neither have they been accepted in the full collegiate sense by their liberal arts colleagues. If the recommendations of this report are accepted, engineering faculty must forsake any notions of independence and isolation and must establish themselves as full members of the university community. They must interact with other professional schools in interface areas and establish and promote greater contact and cooperation with all academic areas of the university community.

It is unfortunate that university organization does not foster such contact and cooperation. Until this can be corrected (see Chapter 7), engineering schools must lead in encouraging and rewarding broad university contacts. Work with the school of education on secondary education should be as rewarding and as rewarded as work with the medical school on bioengineering problems.

To this end, we recommend:

(1) That engineering college administrators recognize, encourage, and reward through released time effective interaction of engineering faculty with nonengineering faculty.

(2) That engineering colleges lead in erasing rigid boundaries and road blocks to effective contact and cooperation between colleges within a university and in establishing new formal structures to encourage and promote the same.

Chapter 5

EDUCATIONAL ROLES AND RESPONSIBILITIES OF INDUSTRY

Engineering schools and organizations that employ engineers have a long history of interaction. The character of this interaction depends markedly upon the employing organizations, which range broadly through a spectrum of private enterprise and governmentally funded laboratories. All of these organizations we describe as "industry."

Successful collaboration between industry and engineering schools is central to the future development of pre-career and lifelong learning for engineers. Programs of collaboration include cooperative work/study, continuing education, consulting, research, and design. In each area of program interaction, both school and industry presumably benefit. For example, in coop education, the school benefits by having its students motivated by industrial experience, by sharpening their career objectives, and by sharing their work experiences with peers. Likewise, industries benefit by the fresh approaches brought by students, by work accomplished, and by the opportunity to selectively recruit engineering talent.

But with these benefits come associated costs. For example, a school cannot provide a coop program without administrative expense; likewise, industry rarely employs the coop student solely on the basis of his cost effective performance. Thus, any program of industry/school interaction must demonstrate its worth in terms of a viable cost/benefit ratio. In coop programs, for example, the school must believe that the costs of administration result in substantially enhanced education, and industry must believe that the costs of training coop employees result in the recruitment and retention of better engineers.

We believe that several programs of industry/school interaction are desirable and marketable on a cost effective basis. Appendix 4 discusses many existing interactions and notes trends in the development of such programs. While many healthy examples are cited, it appears that initiation and maintenance of collaborative programs are inhibited by several factors. The following compilation suggests some of the barriers to increased interaction.

A. Barriers

1. On the Part of Industry

(1) The lack of a tangible direct payoff for interaction.

(2) A perception of schools and faculties as remote from the industrial world.

(3) The lack of an apparent vehicle for interaction.

(4) A benign faith in the educational system.

(5) A willingness to accept the engineering graduate as produced and modify him on the job instead of attempting to modify the educational system.

(6) An in-house expertise and capability for solving problems and doing research without the need for collaboration with schools.

(7) The belief that there is a sharp interface between industrial problems and academic programs.

(8) A need for results on a short time frame which is incompatible with school calendars and scheduling inflexibility.

(9) The expense and difficulties inherent in establishing interactive programs.

(10) The lack of personal contacts with engineering faculty.

(11) An industrial reward system which favors only dollar productivity.

(12) A belief that programs with schools are primarily public relations activities.

2. <u>On the Part of Schools</u>

(1) The geographical isolation of schools from particular industries.

(2) A perception of industry as a diverse assortment with no obvious point of contact.

(3) A reward system which favors achievement in traditional academic areas and does not recognize interaction with industry.

(4) The lack of an apparent vehicle for interaction.

(5) A belief that academics know best how students should be prepared for careers as engineering practitioners.

(6) A difficulty in locating industries that are willing to collaborate in specific programs.

(7) The lack of personal contacts with engineering practitioners.

(8) A tendency for engineering faculty to exist in the educational system without the benefit of industrial experience.

(9) A preference for science and analysis over engineering and design.

(10) The expense and difficulties inherent in establishing interactive programs.

Many of the barriers listed above are similar or complementary. This suggests that solutions may exist which will remove obstacles on both sides. Clearly, such solutions depend upon obstacles that apply to specific programs. The relationship between particular barriers and specific programs is analyzed in Appendix 5.

B. Recommendations

Ideally, the producers and consumers of engineers--schools and industries--should be equally concerned with engineering education. As a practical matter, the fundamental differences between the missions of schools and industry make this impossible. A primary goal of engineering schools is to provide the best possible education to their students. The primary goal of private industry is to make a profit and that of the governmentally funded laboratory is to achieve its mission objective. Industry/school interaction benefits each institution, but the benefits accrue to different levels of priorities within each. On balance, it appears that the initiative for promoting increased interaction will in most cases lie with the schools. Nonetheless, the following recommendations should benefit industry and most require the cooperation of industry.

(1) We recommend that engineering schools appoint an industrial liaison coordinator. This person should be responsible for promoting interactive programs and for coordinating industry/school relations. The appointment should be at the school or college level. In addition, each department or academic unit should appoint a departmental coordinator to work with the school coordinator. The school coordinator should be responsible for collecting data on industries located near to the school. Such data would include information on company size, numbers of engineers, products and activities, and the names of persons responsible for internal programs. The school coordinator should determine overall strategies of interaction as based upon his school's strengths and needs and those of proximate industries.*

*Purdue University's Ball Professor serves in a capacity parallel to that described here.

(2) We recommend that engineering schools undertake a program of faculty visits to industry. The school industrial liaison coordinator, with the advice of departmental coordinators, would direct the program. This group should match individual faculty members with specified industries. For example, a mechanical design faculty member might be given responsibility for industrial liaison with a toy company, a truck industry, and a firm specializing in mechanical vibrations analysis and measurement. The school coordinator would arrange for initial meetings between individual faculty members and industrial people at the specified industries. The goal of the initial meetings would be to explore possible areas of interaction and to have individuals become personally acquainted. Based upon these initial meetings, the faculty visitor should propose specific interactions between his school and his companies. These proposals might include a coop program position, a summer faculty work experience, a research agreement, or a recommendation for no interaction at the present time.

(3) We recommend that engineering schools use the faculty visitation program to obtain information on local industry's needs in the area of continuing education. Possibilities in this area are enormous. Television networks can be established to transmit regular courses to in-house locations. Short courses can accommodate a variety of interests and needs. Special courses can be presented by a regular engineering faculty member to an industrial audience in an in-house format. Video tape delivery via courier coupled with in-house, nonacademic tutors can fill the needs of specified industries. The capability exists and has been demonstrated whereby a high school graduate can earn degrees through the doctorate while maintaining full-time employment.*

Many companies are developing extensive in-house educational programs or subscribing to noncredit, nonaccredited school offerings. Indeed, such arrangements for continuing education can be high calibre and cost effective. Nonetheless, the accredited engineering schools can compete successfully in providing comprehensive high-quality continuing education for academic credit. Certification requirements in this country are such that most professionals prefer accredited academic courses even though they might obtain equivalent knowledge from nondegree granting organizations. Thus, engineering schools should continually work to improve their continuing education programs to insure that they are competive and

*Lawrence Livermore Laboratory has provided such opportunities.

responsive to the needs of industry. A mechanism for providing feedback from industry to allow this improvement is implicit in the faculty visitation and school/industry coordinator recommendations noted above.

(4) We recommend that schools provide a variety of industrial experience opportunities for students. Such opportunities might include coop programs, design project relationships, or special programs. For example, schools located in industrial areas might develop a program whereby the student spends one afternoon per week observing and working with a practicing engineer. Another possibility is a year of internship. Such a program might be developed for students who want to "stop out" for a year of industrial experience, say, following the junior year.

Whatever the program or programs offered for encouraging work experience, schools should concentrate on the educational benefits for many types of students. Theoretically oriented students might find a year spent in a research laboratory to be a worthwhile experience. Students with academic problems are often excluded from special programs; yet, industrial experience might motivate them. Minority and women students, if matched with their counterparts in industry, might develop new insights toward professional success.

(5) We recommend that the school industrial liaison coordinator actively monitor the school placement office. Placement offices should be encouraged to be imaginative and aggressive in placing engineering students in a wide variety of industrial positions. For example, placement of students in small firms often receives little attention compared to that accorded major industrial recruiters. However, small companies can offer a unique combination of opportunity and challenge.

In addition, placement offices might encourage industry to consider alternative forms of compensation to new hires. These might include various blends of salary, geographical location, continuing educational opportunity, work calendar, and profit sharing. For example, a small developing company might offer the new graduate a relatively small salary but significant opportunity for profit sharing.

Faculty members in engineering schools have ceded much industrial contact to the placement bureau in order to avoid interruptions in their work. While this shift has been efficient in many respects, it has perhaps gone too far in many schools, as it has decreased contacts between faculty members and industrial representatives.

(6) We recommend that engineering schools increase the number of faculty members who have had recent industrial experience. This can be done in several ways. First, in appointing new faculty, engineering schools should consider engineers who have established themselves in responsible positions in industry. Perhaps 20 to 50% of the newly appointed faculty should come from the ranks of practitioners. Such faculty can bring a variety of working contacts in industry which can directly benefit students, the school as a whole, and which can facilitate increased industry/school interaction. Second, practitioners should be more widely sought for their teaching and research expertise on a temporary nontenure basis. Such persons bring many of the benefits of their tenure-track counterparts, with the additional advantage of a lessening of the "tenuring in" of the faculty. Third, regular faculty should be encouraged to spend their summers or sabbaticals in industry. Currently, such activity is discouraged both by the financial loss of temporary relocation and by the academic reward system. However, travel grants and a reward system that recognizes the importance of maintaining contact with the industrial world will overcome these obstacles (see Chapter 4).

(7) We recommend that engineering schools establish active industrial advisory boards. Some schools have been successful in establishing "industrial affiliate" programs in which industries contribute an annual fee to the school. In return, the affiliate companies are invited to presentations of research results, design project demonstrations and curriculum conferences, or are provided with limited consulting services. Such arrangements are mutually beneficial. Alternately, individual departments might integrate scattered alumni contacts through an advisory board. The goal of these boards would be to facilitate interaction with industry and to obtain critical feedback regarding the performance of the engineering school.

(8) We recommend that states having agencies, commissions, or boards that oversee the activities of higher education provide statewide coordination of school/industry relations. Such a statewide group should not seek to provide overall policy direction or uniformity of programs. It should, however, serve as a coordinating body to provide liaison between engineering schools and small business and public interest groups. It should publicize programs and capabilities of schools to serve the public interest and commercial interests of the state.

(9) We recommend that ASEE establish a national longitudinal survey of a random sample of the graduates of all engineering schools. The survey should follow graduates at

5 or 10 year intervals and might use a 10% sample (about 4000 per year) of graduates from the classes of 1940, 1950, 1960, and 1970. The results of the survey would include correlations of variables including school (or type of school) attended, earnings, grades in school, highest degree earned, type of career, sex, and so forth. Such data have not previously been obtained on a national scale and would benefit all engineering schools in evaluating their programs.

(10) We recommend that engineering schools establish innovative programs for developing new technical ideas through to full scale production. For example, MIT, Carnegie-Mellon, and the University of Oregon, have programs for spinning off companies with new products. These programs use in-house venture capital and other financial arrangements for the establishment and licensing of new companies. Such programs could motivate students who are interested in design, production, and management.

Chapter 6

FUNDING

There are many indications that the U.S. is not in the mood to provide ever-increasing funds for higher education. If we accept the Carnegie Commission's [1] recommendations to keep funding at 2.5 to 2.7% of the GNP as the probable level for education in the 1980-81 period, costs for higher education must be reduced 20% (1970 dollars). At best, there will be no increases in educational funding that will compare with the increases during the past 20 years. Growth will therefore have to occur through increases in productivity, increases in educational sophistication, and through cost reductions in present programs except where the cost can be passed on directly to the user.

Academic accounting systems are difficult to compare because they are extremely diverse and do not, in general, specify the exact use of funds. As an example, the development of instructional material is sometimes covered by gift money, foundation money, contract funding, or school operating money. However, it is often done during the "free time" of a faculty member, which may be covered by research funding or other salary sources. Some continuing education expenses are budgeted directly by industry. However, other educational activities are charged to job numbers or general overhead accounts.

Many members of the educational community feel that budget allocations should be general, in order to allow academic judgement to be exercised and to prevent undue input from segments of society who do not understand or are not sympathetic to the problems of education. Faculty members resist the type of simplistic measures (student credit hour) used in many budgetary practices, and state supported institutions attempt to budget as broadly as possible in order to retain as much local decision making capability as possible.

We agree that academic decisions must be made by academic professionals. However, we feel that funding and budget allocation procedures for universities must be improved. Large, multi-campus systems especially must have a better method of allocating funds to various campuses on a fair and reasonable basis. Within universities, the allocation of funds to various academic units must be made on a more rational basis. The higher cost of some programs (such as engineering) must be recognized and treated openly. Models for university finance and allocation are needed which are based upon the incremental cost of delivering a specific unit of output of education. Only then can schools look rationally at the financial effect of changes.

The best example of a set of funding formulas we were able to find is that prepared by the Coordinating Board of the Texas College and University System [2]. This approach is explained more fully in Appendix 6. The Texas formulas provide a nearly complete funding model for a university system and also give considerable detailed information on how costs are distributed. However, they do not reflect the number of graduates who complete programs and move into a productive place in society. Present funding models tend to count only student credit hours. Future models should give recognition to effort which successfully guides the student to graduation and on into society (modified by recognition of the primary effort of the institution, such as teaching, research, or professional training).

Recommendation: Engineering schools (and institutions of higher education in general) should develop better models of the educational budget, which reflect detailed expenditure of funds in such a way that the effect of innovations in educational approaches could be evaluated. Accounting systems should be standardized so that comparative costs could be used by schools as a measure of effectiveness.

Although specific educational costs were difficult to determine, it was obvious in this study that engineering schools have a student problem which casts them in a budgetary bad light and which must be rectified, that engineering schools must cut costs in some areas so that they may move into newer and critical areas, and that some things can be done to improve the funding situation. The remainder of this chapter therefore contains recommendations in these areas.

Engineering education must compete successfully in the market place for students if it is to be able to continue to function in the higher education system in its present manner. If students decrease in number, some adjustment must occur, such as a decrease in the number of schools offering engineering. Authors such as Terman [3] strongly recommend eliminating engineering programs that are not large enough to be economically efficient. He has defined the critical size as a schools that graduates at least 125-150 students per year with 3 or 4 major curriculums with each graduating 40-50 BS students per year.

The new directions recommended in Chapter 3 provide a rationale for funding new students and thereby broadening the financial base to retain vigor in our engineering schools.

Recommendation: Funding patterns should be consistent with attracting a broader variety of students to engineering in order to reacquire some of the relative economies of scale that engineering education used to enjoy.

Cost Reduction

In order to make funding available to establish the new programs and directions engineering education continually requires, it will be necessary in the future to cut costs in existing activities. Toward this goal, we recommend the following.

Recommendation: Engineering schools should eliminate marginal programs.

Recommendation: Well documented innovative teaching techniques should be implemented where possible to increase productivity and improve the teaching program without expensive trial periods.

Recommendation: Organizational units within engineering schools should be combined to reduce overhead, reduce duplication of equipment, and to better utilize space.

Recommendation: Underutilized laboratory facilities should be centralized, combined, and shared. Engineering schools should set up programs of sharing specialized facilities, especially in situations where the pace of equipment development makes it difficult for a single school to remain current. (Nuclear reactor laboratories)

Recommendation: Engineering schools should decrease duplication in coursework.

Changes in the Funding Situation

Engineering schools can benefit from certain changes in local and governmental funding patterns. We recommend the following.

Recommendation: Engineering schools should develop increased avenues for industrial support through university-industry faculty employment, student co-op, expanded research extension and continuing education programs, increased use of industry-defined problems and support, and similar activities.

Engineering education in the past 20 years has been following a direction somewhat divergent from most of industry. It has been pointing toward what is commonly referred to as "high technology" and the level of technical sophistication more commonly found in aerospace, weapon development, and in industries (such as the computer industry) which are limited by technology. It has tended to ignore the large segment of industry which is involved in the production of consumer goods. In that sense, it has moved off-center. It could benefit in many ways from a closer association with industry. One of these is financial. Cost data collected from industries in the San Francisco Bay Area and discussed in more detail in Appendix 4, indicate expenditures for employee education in the range of $175 to $400 per engineering employee. Considering these values as conservative figures (many educational expenditures are hidden in other budget items) and using the approximately 1,100,000 engineering employees in the country as a base, this represents a potential revenue source of $192,500,000 to $440,000,000 per year. Some of this funding is already going to universities in the form of tuition and through extension and continuing education programs. However, many industries present some in-house form of continuing education and various commercial firms are in the business of selling short-courses, especially seminars, and other types of training programs. If cooperation between industry and the universities can be further enhanced, additional funds and students will become available.

Recommendation: Federal and state sponsored research must be maintained by recognizing shifts in public emphasis.

There are many disciplines in the universities outside of the engineering schools now receiving funding on applied problems which could have well become defined as "engineering" problems. Planning activities have sprung up outside engineering, as have programs concerned with the environment and with the use of modeling techniques in complex social situations. Engineering's reluctance to leave "traditional" areas (which are continuously in change) has resulted in the loss of research funding which could have been obtained by closer attention to the needs of society.

Recommendation: Funding procedures, especially in large state university systems, must be changed to encourage flexibility and innovation.

Many large educational institutions are now funded through a central authority, and consequently, little is done to encourage individual campuses and faculty members to develop their own unique plans. Often one year's funding pattern is based on that of the year before, with little room for innovation and change. The funding agencies are not solely responsible for the dilemma, since existing departmental structures of schools often reduce flexibility and inhibit institutional responsiveness to community and national needs. Since expansion will not be able to provide the support for change in the future, flexibility must be built into the funding system.

Recommendation: Revise student support patterns, with increased availability of loan money, portability built into all loans and grants, and raised tuitions in public engineering schools.

Current loan programs in our higher educational system do not appear to meet the needs of students [4]. The additional earnings a college graduate can expect above the earnings of a high school graduate has generally been accepted as approximately $200,000, although this figure may be decreasing. With this expected additional lifetime earning potential, it is reasonable to consider a loan to finance a good student as a sound investment. This should be in the form of a program which is readily available, with long term repayment periods, say 20-30 years (similar to the Yale plan), allowing the student to finance his or her education without fanfare.

The main obstacle to separate loan funds in public universities seems to be the initial money source. For this reason, the Sloan report [4] suggests that most institutions could operate within the framework of GSLP (Government Sponsored Loan Program) if the loan paper can be effectively marketed (one of the present problems). The Federal government, through the federally sponsored private corporation, the

Student Loan Marketing Association or "Sally May," is developing secondary markets and warehousing potential that will encourage educational institutions to participate to a greater extent.

This study concludes that a sizeable proportion of loans to students should be "portable." The student would deal directly with some central agency for the funding, then be free to select the institution of his/her choice. There are advantages and disadvantages to this approach. Two of the advantages are that

(1) the student may select his institution irrespective of financial constraint,

(2) the educational institutions are placed in a competitive market, encouraging improvement.

Two disadvantages are:

(1) Planning on a year-to-year basis might be difficult for some universities because of uncertainty of student numbers.

(2) The creation of a large, very influential bureaucracy to administer the loans and grants might occur.

However, we feel that the advantages outweigh the disadvantages and that educational loans should be available independently of the educational institutions.

On the subject of tuition, it is estimated that tuition represents 20% of the cost in public universities and 50% in private universities [5]. If loans are readily available to qualified engineering students, it seems reasonable that the tuitions, at least at the public engineering schools, should be raised. This is in line with the recommendations of the Committee for Economic Development [5]. The financial burden of engineering education can therefore be transferred to the increased earning potential of the student. The argument that students from low-income families are precluded from engineering education by higher tuition <u>must</u> be answered with appropriate loan and grant policies.

References for Chapter 6

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4. The Sloan Study Consortium, Paying for College-Financial Education at Nine Private Institutions, The University Press of New England; Hanover, New Hampshire, 1974.

5. Committee for Economic Development, "The Management and Financing of Colleges," New York, 1973.

Chapter 7

INSTITUTIONAL OBJECTIVES AND GOALS

A. Introduction

Educational institutions often act either as if they do not have specific objectives or as if they cannot focus their efforts to reach their objectives. They often try unsuccessfully to do too many things, and their various factions, particularly the faculty, do not direct their efforts to satisfying overall university objectives. Three sets of recommendations are offered. The first set concerns types of objectives for the institution. The second set relates to the process of selecting objectives. The third set involves control of the institution as it moves toward its objectives.

The educational institutions considered here are universities because of their wide variety of activities. The recommendations should interest schools of engineering within universities because the health of the university affects the health of its parts. The recommendations should interest colleges, such as community colleges, which now serve well defined roles because such institutions tend to expand the scope of their activities and thereby become defocussed.

B. Identification of University Objectives

Professor James G. March, formerly a Dean at the University of California, Irvine, observed [1], "The conspicuous thing about universities is what they ain't got--goals or technology." Actually, it is probably more accurate to say that the universities have too many goals rather than none.

It may be useful to list some of the activities performed by universities, as these activities may reflect goals and thus try to determine the bedrock nature of a university. A partial list of university activities is:

(a) transmission of knowledge

(b) generation of knowledge

(c) socialization of students

(d) acting as a guru to society

(e) hotel administration

(f) public entertainment via sports, concerts, and so forth

(g) investment brokers

(h) task force centers for social or governmental missions

(i) an enhancement of upward social mobility

It would be easy to go on, but these nine items represent areas into which colleges and universities have moved. All parts of society do not agree that all of these are equally significant.

Some people argue that hotel administration (the operations of dormitories and apartment complexes), for example, is not part of a university--that this would be better left to private or separate governmental institutions which can do it better, possibly at lower cost. Others argue that, since students require not only cognitive knowledge but also knowledge of people, an important aspect of a university's operation should be the operating of dormitories, apartment complexes, and cafeterias, so that students can learn to live together, in preparation for living in society. If the university provides this experience and views it as important, then dormitory operation can be much more than housekeeping. It can be a socialization process for the students.

Public entertainment via sports and concerts is an important function, some say, of a university. They argue that universities should provide concerts, speakers, debates, sports, and so forth, for the populace at large. These things may aid society to view the university favorably and contribute to university support. Public lectures and cultural events show that the universities are not ivory towers, aloof from society, but are involved in society. University involvement could improve the quality of entertainment available. Still, others argue that providing concerts, speakers, and sports is peripheral to the academic nature of the university and that these activities should be contracted out or even eliminated entirely.

In any case, the wide range of things into which universities can move and which have been demanded of universities, has diluted the institutional mission. There is a fragmentation of attention, a cacophony of sounds, a pluralism or a confusion, so that it is difficult to tell precisely what the university is doing. Students and faculty are caught in this counter-productive context of chaos.

However good the arguments for each activity may be, the totality may become almost unmanageable. For survival, institutions must define their institutional missions. Each engineering school must define its mission. Engineering colleges have, to date, focussed on relatively few objectives, but have done it, essentially, by minimizing the number of their activities, while depending on the university to provide the others.

One reason universities have become involved in so many activities is that they have simply reacted to requests presented by students, government agencies, alumni, etc. We feel the universities should consciously plan what they will do. The first step is to determine the set of needs to be filled. The point of recommendations 1, 2, and 3 below, is that universities should look outside for guidance.

Recommendations Having to do with the Delineation of Goals

(1) When universities, or engineering schools, or departments, debate and establish policies, all constituent groups should be effectively represented.

We recommend that each engineering school, or, depending on the size of the faculty, each engineering department, set up visiting committees to guide the formation of overall educational objectives.

These committees would contain not only successful engineers and educators but recent alumni, secondary school faculty, potential employers of graduates, and others. Too often such visiting committees have been selected from the ranks of potential financial donors or leaders of educational institutions with similar philosophy and have not contributed new ideas.

The details of the committee's function should vary from institution to institution. Initially, the committee might poll its members' constituencies--students, faculty, alumni, industrial and community leaders, high school teachers, etc. It might observe classroom activities. It might sponsor a conference on educational objectives and their importance. After the initial study, less elaborate ways of gathering information would probably suffice, but the committee should continue to meet regularly, perhaps several times a year. It would probably work most efficiently through subcommittees.

We applaud the effort done along these lines at the University of Washington. Starting Autumn 1973, the University of Washington requires that a department prepare a set of objectives covering the functions of education, research, and service, every two years. Budget requests for long term (2-6 year) planning of the department must follow the list of goals and objectives. The objectives are prepared by students, faculty, and staff, assembled by the university into a planning document and coordinated with the university's request for state funds.

We also understand that Dartmouth, Lehigh, Stanford, and Ohio, among others, have visiting committees for their engineering colleges.

(2) The engineering professional societies can contribute a useful point of view.

We recommend there be standing debate in professional societies on the directions of education, on the directions of industry, and on the interface between education and industry.

Most engineering professional societies have active educational committees. These committees could coordinate the debate to be carried on at national meetings, special conferences, and through the professional journals. The results of the debate could be published just as professional societies now publish standards as guidance for the profession.

(3) Estimates of the influence of the Board of Trustees in a university vary [2]. Nonetheless, they can be a significant force, especially in a time of crisis. Certainly, trustees with an engineering background could contribute greatly to the direction of a university.

We recommend that trustees of the university should be chosen differently so as to encompass a more heterogeneous sample of society.

Most Boards of Trustees of colleges and universities are composed of people who have been successful in business, government, or some profession [3]. Engineers seem to be under-represented. Board members should be chosen carefully for the contributions they can make. Engineering training may give an especially needed point of view, both for the engineering college and the university as a whole, to trustee deliberations when difficult choices of priorities must be made.

C. The Selection of Objectives

Mayhew [4] suggests that in a time of expansion when students and money are plentiful, a university can successfully be all things to all people, but in a time of steady state, choices must be made and institutional distinctiveness attained. The process will obviously be more successful if it is done rationally. The clientele served should influence the choices. So should the uniquenesses of the existing institution. Objectives must not become too narrow, or institutional health may suffer. Educational institutions have had remarkable success at survival compared, for example, to commercial institutions. One reason may be the redundancy inherent in an institution pursuing a variety of objectives with a variety of clientele. However, university resources must be allocated so that clearly essential programs are not starved to maintain a wide variety of programs. Well-thought-out objectives are necessary for this goal.

Recommendations for the Selection of Goals

(4) Given a list of possible goals, generated at least in part externally, by the groups described in recommendations 1, 2, and 3, above, the university must select those it will fulfill.

We recommend that this selection be done so as to result in a published statement of specific educational objectives. These objectives must be stated precisely enough so that the university's success at meeting them can be measured.

For example, one objective might be that an electrical engineering student be able to design, from standard logic circuits, a digital device of complexity equivalent to an up-down counter. Another objective might be that the student be able to analyze a problem using second order partial differential equations. A third objective might be that the student be able to describe how technology could satisfy a particular economic need.

Faculty members would use these objectives to plan and to evaluate their courses. Academic administrative officers would use them to study the effectiveness of programs. Parents and students would find them helpful both to select fields of study or institutions and to evaluate progress toward goals.

Statements of purpose in university catalogues are often too vague to allow discriminating between institutions. Further, it is not easy to decide if an institution is in fact working effectively toward these purposes as stated. The statements of objectives recommended here could be considered analogous to contracts, or warranties, between the student and the university--"the university agrees to do these things for each student before graduation..." Such statements of objectives might make the choice of institutions more rational for prospective students, although their primary purpose would be to assist the educational institution in focusing its efforts.

Of course, a university or engineering school could also generate and publish another statement of purpose, describing its distinctive character, written especially for those who might want to enroll. These statements would be more believable if success at meeting objectives could be included with the statement.

(5) It is not efficient for every educational institution to try to do everything. Each educational institution should consider its list of objectives together with the lists of the universities it normally competes with and also with lists of the needs and strengths of related noneducational institutions.

We recommend universities and other institutions which are in the same region, or which for some other reason may have overlapping objectives or clientele, form groups to decide how the members of the group can together satisfy their objectives.

For example, only some institutions of the group may decide to develop educational programs in a particular new area. Education of certain students in certain subjects may be done most efficiently in government laboratories where unique facilities or special expertise is available. An advantage of interinstitutional cooperation is the encouragement it gives each institution to develop its own distinctive character.

There are many precedents for this sort of cooperation. The state universities of New England have formed the New England Consortia, essentially making certain curricula unique to certain schools available to all residents of participating states. Nearby graduate schools, e.g. M.I.T. and Harvard, allow graduate students to take courses at any university of the group with a minimum of administrative procedures. The 3-2 programs jointly offered by a pair of schools, for example, Pacific Lutheran and Stanford, are another example. Here students take their first 3 years of basic engineering studies at one school, with an opportunity to include many liberal arts courses, and 2 years of advanced work at another school--making use of the advantages of both schools. Regional cooperative ventures exist in the Portland, Oregon, Atlanta, Georgia, and Connecticut areas, among others. Chapter 6 suggested that nearby institutions develop new laboratories together, not duplicating seldom used expensive equipment.

A drawback to having each school develop distinctive strengths is the inconvenience for students whose educational interest change. Increased use of educational technology may reduce significantly this inconvenience, as will increased ease of enrollment in courses at different schools.

(6) As mentioned above, universities have entered a wide range of activities, not always by design.

We recommend that administrative officers at each university review their procedures for evaluating the desirability of the formation of new activity centers.

These decisions require a balance between stimulation of innovation and resistance to diffusion of mission.

Nearly every engineering school has its own example of the establishment of a major effort without general faculty or administrative knowledge and without real concern for the educational implications. Often these new efforts are externally funded. The attitude, "If it pays for itself, we don't object," has brought many ancillary operations to the campus that have deflected the attention and effort of the university from its primary task. In particular, undue faculty attention is often required to maintain the level of funding originally achieved and this effort diminishes that available for instruction.

(7) Engineering schools operating in institutions where objectives and policies are set in academic senates have a special problem. For efficiency, engineering students take service courses in other fields. However, in the university framework, engineering students at the freshmen-sophomore level take predominately service courses in math, physics, chemistry, and general education courses such as English, history, etc., taught by the respective departments. The high attrition rate among freshmen and sophomore in engineering, coupled with high percentage of the early courses that are service courses, means that engineering students in service courses generate

Student Credit Hours, justifying additional faculty space and monies outside of engineering. Even in technical or polytechnic universities, engineering is sometimes becoming subservient to other departments and schools due to the additional faculty and votes in academic senates generated partially by engineering dropouts.

Although a typical engineering program includes a minimum of one half year of science and one half year of math, all taught outside of engineering, there are little or no reverse service offerings, i.e., other disciplines do not generally take engineering courses. Yet, most nonengineering disciplines have a substantial number of free electives. Moreover, all students could benefit from understanding modern technology.

(a) We recommend that Academic Senate representation be revised to more truly represent individual areas.

This can be accomplished by continuing representation from individual schools based on the total number of faculty but allowing additional representation from each school based on the total number of student majors enrolled.

(b) All university students should be required to take one or more courses in engineering, specifically designed for this purpose.

D. The Implementation of Objectives

The recommendations just described concerned choosing objectives. Objectives should be made specific enough so one can observe if they are satisfied. The choice should consider financial data from other universities and the strengths of neighboring institutions. Administrative procedures should be tightened so universities do not pursue all possibilities, and, when applicable, academic senate representation should be revised.

The final set of recommendations concerns the strategy for attaining the objectives chosen. The obstacle here has two parts. The first is deficient management procedures--lack of a continuous assessment of how the objectives are being met, failure to use available management skills, failure to communicate objectives to the faculty. The second part is the faculty tending to pursue their own objectives, rather than those of the university. Recommendations 8, 9, 10, and 11 address ways of attaining the chosen objectives. Recommendations 12 and 13 address objectives held by faculty members.

Recommendations Concerning Working Effectively Toward University Objectives

Every control engineer knows that a closed loop system performs better than an open loop one, in the long run. This principle also applies to educational systems. Thus, the educational program should be monitored to determine how well the selected objectives are being satisfied. We recommend two evaluation committees, one internal and one external.

(8) Each engineering school should have a watchdog committee. Many people will resist this idea and ambitious faculty and administrators can easily subvert it. Nonetheless, if universities do not choose to evaluate themselves in a real way, someone else will evaluate them despite complaints that the evaluations are unfair or limited or distorted. Universities must recognize that they must evaluate themselves.

We recommend ongoing internal evaluation mechanisms including faculty, students, administration, noninstitution people, nonacademic people, political people, public school teachers, etc.

Recommendation 2 proposed a visiting committee to assist in determining objectives. The evaluation committee recommended here could be identical to, distinct from, or partly overlapping with that visiting committee, depending on local conditions. If the committees are distinct, they should certainly communicate and cooperate.

(9) We recommend that professional societies contribu' evaluation.

There should be standing committees and standard evaluation techniques to help universities assess themselves. These committees would make general recommendations on the product of engineering education, which individual engineering colleges could interpret for their own situation. The committees could guide particular schools when asked but would not require conformity to a standard. They would develop methods for engineering schools to judge whether they meet their own specific objectives.

Obviously, there will be interaction between the role of professional societies as recommended here and the role of ECPD as an accrediting agency. The intentions of the professional society are actually quite different in the two roles--here they are making information available for the schools to use in their own evaluation. The accreditation role is discussed in Chapter 8.

(10) The functioning of organizations, including universities, depends on how the members relate their objectives to that of the organization. Thus, we look now at the objectives of the faculty. There seem to be two reasons

why the objectives of faculty members do not coincide with those of the university. One of these reasons is the organization of the university, the subject of Chapter 8. The other is the way rewards, both financial and professional, are dispensed.

One reason that faculty do not always do a good job when working toward university rather than departmental objectives, e.g., counseling undergraduates, is that they do not get paid for it directly.

We recommend that variants of the compensation scheme be studied so those who accomplish more are paid more.

After all, other professionals such as physicians and attorneys, can adjust their level of effort in proportion to their desires. Educators should be able to do this also.

It is probably wise not to have faculty salaries depend primarily on the number of students taught or the amount of research accomplished. On the other hand, an introduction of some elements of the marketplace into the university might stimulate better performance. As Coleman [5] points out, at present only the exceptional teacher rescues significant reinforcement for teaching. If the university system allows students to choose instructors and if consistently well regarded instructors are rewarded, then good teaching will be reinforced.

An organizational structure proposed in Chapter 8 demonstrates one way that salaries could be tied to performance, while ensuring a base salary for all faculty members.

(11) Another reason faculty members may not strive wholeheartedly toward implementing university objectives is the value system of the university. It does appear that we, both in the colleges and in society at large, respect the researcher more than the teacher.

We recommend universities try to make the prestige of other educational activities, such as instruction and counseling, as great as that of research. (This assumes, of course, the university administration does in fact value instruction and counseling as highly as research.)

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Chapter 8

HIGHER EDUCATION ORGANIZATIONAL STRUCTURES

The first three chapters of this report described the present and our concerns about the future of engineering education. The remaining chapters describe obstacles that impede necessary changes and strategies for meeting the obstacles. Chapter 4 dealt with the faculty and some of its characteristics. Chapter 5 concerned industry's responsibilities, Chapter 6 dealt with finances, and Chapter 7 with the multiplicity of university objectives. This chapter describes how it all--faculty, money, objectives--can be brought together into a functioning whole. That is, this chapter discusses the organizational structure of the university.

Three themes run through the discussion: (1) a concern that non-academic administration may dominate universities, (2) a question whether the departmental structure is the best structure for all universities, and (3) a concern that many universities are becoming too large and thus communication between parts, e.g., faculty and boards of trustees is becoming strained. In each case, the organizational structure hinders the functioning of the university. This hindrance is the obstacle of concern here.

A. The Situation--Organizational Features of Universities

Here we describe the characteristics of a university organizational structure which seem to influence most strongly its response. A university is a big business with most of the management problems of big business. Because faculty consider themselves professionals, the employee-employer relationship differs from that of most other large organizations. We saw in Chapter 7 that universities have several goals and performance toward some of those goals is difficult to quantify. Decision-making tends, in practice, to be diffused in a university. Finally, there is a rather widespread feeling of ambiguity about the role of university administrations. We will consider each of these characteristics in detail. Again, this discussion primarily concerns universities, which have inherently more difficult organization problems than colleges.

The educational leadership function can easily be confused with the management function, that is, with the provision of central services such as payroll, research grant compliance, registration and scheduling, etc. Clearly, some universities are better managed than others and clearly if some universities are not better managed, especially financially, they will close. Equally clearly, decisions based on business considerations can significantly impact educational policy.

Dissimilarities have been noted between the organization of a university and that of a business, governmental, or military agency [1]. The scalar principle, "the grading of duties not according to function, but according to rank" does not apply. For example, assistant professors seldom perceive themselves as working for associate professors, nor associate professors for professors. Many faculty perceive themselves as working at a university rather than for a university, just as physicians think of themselves as working at a hospital not for a hospital.

We saw in Chapter 7 that universities and thus university administrators have many goals, including instruction, research, service, and the maintenance of institutional prestige. Some of these goals, like those having to do with research or prestige, can be more or less clearly articulated. Some, like those dealing with educational (academic) policy, are difficult to articulate operationally, partly because it is difficult to assess one's effectiveness. For example, a major problem, as we saw in Chapter 7, is to evaluate the functioning of an instructional program or, as we saw in Chapter 5, the teaching of a professor. The difficulties of centrally managing an institution by objectives without clear measures of progress are self apparent. The problems are further complicated by broader conflicts between academic policies and other policies (fiscal, physical, social, etc.). Actually the problem of applying modern management concepts to university operation is a fruitful area of research.

The ingredients of a proper decision are well known [2]. The decision maker must understand the objectives desired and know alternatives and the implications of each alternative. (Many decisions, at least in the academic world, have only trivial significance either because there are no viable alternatives or because the implications of the various alternatives are nearly identical.) Sensitivity analysis is a way to evaluate the significance of a decision.

A fundamental purpose of an organizational structure is to allow decisions to be made at the proper level. If decisions are made too high in a university, at the president's level or above, the decision maker may not realize the implications of alternatives. On the other hand, if decisions are made too low in a university, at the individual faculty member's level, the alternatives are usually clear, but the objectives may be those of the faculty member and the decision may not serve the institution well.

In universities, important decisions are made nearly everywhere. Faculty usually decide classroom activities and to a large extent course content. Professors themselves normally decide how to do their research. Housing offices often are fairly independent in their day-to-day operation. What passes for university policy is really the integration of many decisions made at many places.

Many feel ambiguous about the role of university administration. A classical view is that the university exists solely to benefit students and faculty, and administrative and support personnel should only facilitate development of an optimum environment for faculty and students. Under this view, administrators should maintain low profiles while removing obstacles before the faculty and, most of all, should avoid becoming obstacles themselves. In short, they should be good servants. An alternate version is that certain administrators--department chairmen, deans, and perhaps the president--are both good servants and, in certain matters, good leaders. In either version, the department chairmen, deans, and perhaps the president are a part of the faculty working toward common goals with them.

While either view may be seen as an ideal, the modern higher educational institution finds neither readily achievable. In most educational institutions there is a trend toward more centralized decision-making as external constraints on universities increase. This shift has not enhanced the role of department chairmen, deans, and presidents as either servants or leaders of faculty but has eroded it. It has either changed their role as a part of the faculty or has forced or encouraged them to turn over decision making power to a nonacademic bureaucracy while retaining only a few narrowly academic decisions. In this latter case, most of the budget is committed and many of the important decisions are made before the academic sector can make its input.

B. <u>The Obstacles--The Actual University Organization</u>

The actual organizational structure of a university differs from its apparent structure. This section talks about the location of power--the capacity to make significant decisions and implement them--in a university.

The university president is the chief governing officer and therefore appears to control most of the power. This may have been true in the past. But, to quote from Lewis B. Mayhew's [3] critique of a report by Michael A. Cohen and James G. March [4], "observations point to a distinctly limited presidential role. A president probably has more power than other single individuals but he generally does not dominate decision making."

For almost all faculty, the major connection with the university is through the department. Department chairmen usually are responsible for communicating faculty opinion to the administration and interpreting administration wishes to faculty. In most institutions, faculty have de facto if not de jure control of the curriculum and, as few professors question the courses or program organization of another department, each department sets its own curriculum. Many faculty consider themselves basically members of a particular department, not of a particular university. The result is that many significant educational decisions are actually made at the department level. One critic describes it as a "policy of drift."

The implications to the university of making decisions at the departmental level are obvious. The department's objectives often attempt to further its discipline, increase the department's rank within the field, or improve its faculty. These are laudable objectives, but their accomplishment may not improve the quality of education offered to the great majority of students.

Two situations are often cited to demonstrate how optimum decisions for a department may be sub-optimal for an institution. The first is the responsibility of a department toward students who will not do professional work in its field. The second is acquiring and keeping faculty whose primary interests cross departmental lines. In an era when resources were growing, an enlightened department chairman could serve both the department and the university. Today, however, the basic motivation of a department chairman is to act in departmental self-interest, often avoiding consideration of university concerns. The department role thereby becomes increasingly narrow and academically focused and more power flows to the nonacademicians.

Within a single university, the problems are compounded by the increasing wealth and strength of the nonacademic bureaucracy. More and more the business manager, legal counsel, security officer, facilities head, affirmative action officer, admissions director, financial aids officer, housing director, health service head, employees union chief, and a growing host of others, are making decisions that consume the budget and set the tone of the university. After these decisions are made, the deans and department chairmen make their less and less significant decisions about courses, programs, faculty, and students.

Those who believe in faculty control may view this as a grab of power from the legitimate heirs to decision-making, the faculty, but this may not be entirely fair. The financial aids officer and the housing director do handle large sums of money and the increasing crime rate may require a large security force and a competent director. Their decisions are important. Compliance with government regulations have required large administrative staffs--e.g., grants and contracts accounting or OHSA offices. Faculty traditionally have not been involved in these affairs. Perhaps faculty and their leaders have not lost control but have surrendered it.

The second obstacle relates not so much to the fact that someone other than the faculty is handling nonacademic matters but that those who are handling them are not fully aware of or primarily concerned with education.

In Chapters 4 and 5 we recommended that faculty spend extended periods in industry. We have found through our own experience that faculty members sometimes encounter significant administrative difficulties at their university when they try to do this. The personnel, budget, etc. offices are simply not set for these kinds of activities, although they have great educational value.

Chapter 7 discussed the necessity of evaluating performance of faculty. A problem related to organizational structure is the usage of such evaluation of a professor's educational effectiveness. Through personal communications, we estimated that nearly 80% of U.S. engineering faculty are now tenured. Differential salary adjustments for good or poor performance are possible but rarely used, probably just because of the difficulties of recognizing good or poor performance. Faculty are notoriously reluctant to evaluate one another (see Ref. 1, Chapter

8), and few deans, much less provosts or presidents, can judge the competence of those in an alien field. Thus, the administration finds itself largely unable to recognize or reward quality in its faculty. This inability has major implications for university governance.

There are other sources of power in a university. Students are one and organized labor another. The recent incorporation of student elements at all levels, including Boards of Trustees, attests to their recognition within the governance structure. Where in the past the University enjoyed a near autonomous relationship with labor, various reasons, including federal legislation of the past decade, have emphasized the requirement to deal explicitly with employees, either individually or through unions.

The sheer size of a university and the difficulty of motivating all elements at once giving it inertia, is the third obstacle in this chapter. When a university becomes large, students and faculty may have trouble merely identifying the offices responsible for nonroutine problems. For example, who should be notified if a student is using the university computer to process records for an illegal drug business? Who allocates funds for supplies used in interdisciplinary courses?

Another problem in a big institution, where each decision affects many offices, is gaining access to decision making groups. A faculty member with an innovative proposal may be stymied when going through the normal channels, often simply because the offices in those channels are overburdened and unconcerned with possible implications of innovation throughout the institutions.

C. The Strategies--Recommendations Concerning University Organizational Structure

Above, we described three obstacles to change arising from the organizational structure of a university viz: the influence of academic departments, the growth of nonacademic administration, and the size of most universities. In this section seven recommendations are presented, most of which speak to more than one obstacle.

The first recommendation is basically that existing organizations be used more effectively. The second recommendation proposes a new structure, in which form follows function. The third recommendation concerns reorienting both departments and the business offices. The fourth concerns integrating people from various parts of the university. The next recommendation discusses a specific structural change. The sixth recommendation concerns the size of universities and the last, communication channels.

(1) The history, political situation, personalities, etc. will differ markedly from one institution to the next, and so strategies for change cannot be the same. For example, in some universities a forceful and committed dean or president might effectively modify the reward

structure as suggested in Chapter 7 to improve the educational climate. In some institutions, faculty members may have let themselves be cowed unnecessarily by demands from offices of research administration or by the unwillingness of registrars to make information available. The present organization structure might work well if it were used properly.

We recommend that presidents, deans, and faculty, possibly through committees, devote major attention to the uses of existing university structures. This analysis should discover whether particular offices are underutilizing or overutilizing their power, that is, whether the planned structure is being followed.

(2) At some universities, a major reorganization may be needed.

We recommend that if a major reorganization is needed, the matrix or project scheme explained next, be considered.

In this organizational structure, designated offices have responsibility and authority for instructional programs and are primarily concerned only with those programs. The structure is similar to the so-called "project" or "matrix" structure used in many industrial or government laboratories [5]. An example of use of this structure in a university is shown in Figure 1. Each faculty member affiliates with two different types of organizations--groups divided according to academic disciplines, and programs, corresponding to the various activities performed.

In Figure 1 the groups correspond to the columns of the matrix. These groups resemble academic departments but the title "groups" is used here to avoid the connotation of "departments." Most faculty will be in the group corresponding to their field of engineering. Those faculty whose fields do not correspond to existing groups either form groups of their own or are placed for administrative purposes in a special group labeled "Interdisciplinary" in Figure 1.

The rows in Figure 1 represent programs. The essential point of the organization is that graduate and undergraduate instruction are programs or, at all but the smallest universities, sets of subprograms. Responsibility for each of these programs rests with program managers. Academic advising is another program. Administrative tasks or major committee responsibilities may be considered programs. Research projects are programs. A given faculty member will probably participate in several programs, that is, be an entry in several rows of the matrix in Figure 1.

The work of the program managers for the various undergraduate instructional programs is to organiz the program, evaluate, and supervise it. To formulate program objectives, the manager might consult the visiting committee proposed in Chapter 7, composed of people from industry and government laboratories, graduates of the program, parents of

	Aerospace Engineering Group	Bio-Medical Engineering Group	Mechanical Design Group	Interdisciplinary Faculty Group	etc.
Aerospace Engineering Undergraduate Programs					
Bio-Medical Aerospace Engineering Under-graduate Programs					
Common Freshman Programs					
Aerospace Engineering Graduate Programs					
Bio-Medical Engineering Graduate Programs					
Undergraduate Academic Advising					
Bio-Medical NSF Sponsored Research Program					
Aerospace NASA Sponsored Research Program					
University Sponsored Research Program					
etc.					

Figure 1. EXAMPLE OF MATRIX UNIVERSITY STRUCTURE.

students, community leaders, etc. The manager would also consult educational authorities and faculty in the disciplines pertinent to the program.

The intention is to develop as effective a program as possible in, for example, civil engineering with as little bias as possible introduced by particular professional interests. Once the program is planned, the manager of the undergraduate civil engineering program negotiates work with the group leaders or directly with individual faculty to staff it. (Presumably, the bulk of the staffing comes from the civil engineering group.) When the program is functioning, the program manager monitors it and makes changes as required. Obviously, evaluating teaching effectiveness is essential if the monitoring is to be useful.

Program managers must control the budget. In this matrix structure all the money allocated for instruction passes through the program managers. A faculty member who wants to earn money teaching must be accepted into a program by a program manager, normally through negotiation with a group leader.

The program managers responsible for undergraduate programs are themselves responsible to a director of undergraduate instruction. This director, obviously, is concerned with the overall quality of the undergraduate education. The director also is concerned with the development of new programs as appropriate and the phasing out of old ones. This director manages the total engineering college undergraduate instructional budget. He may also handle other programs such as undergraduate counseling or a common freshman program.

Graduate instructional programs function in the same way, with a director and program managers. Research programs are managed slightly differently. Externally supported projects are usually managed by the faculty member obtaining the grant or contract, with the director supplying only administrative, e.g., clerical or legal support. The director of research would, however, have some university funds to develop new research areas under university sponsorship.

A major task of the directors of instructional programs is to improve the teaching ability of the faculty. They would organize and direct teaching as recommended in Chapter 5 and administer other projects supporting educational innovation.

Discipline group leaders develop and maintain technical strengths in their areas. They hire most faculty. They evaluate the technical competence of faculty in their groups. A major part of their job is helping faculty members maintain their professional ability and helping younger faculty to advance their skills. The group leaders might coordinate promotion and tenure decision making, receiving recommendations from the program managers. They would handle administrative chores, offices, staff services, etc. for their group. They would be in charge of central laboratory facilities, used in several programs.

The discipline group leaders obviously would have a budget for their administrative chores. Central laboratory facilities would be purchased as capital items and charged as used to programs. Groups would also have a budget to support faculty who are not fully supported on programs. Such funds would be limited and might be used to develop new areas. Thus, an important task for discipline group leaders is to identify significant future technical fields.

There would be a coordinator for the group leaders council with a major responsibility for planning. The coordinator would administer activities which are most efficiently done on a college-wide basis. (The coordinator is the approximate analog to the Dean of Engineering in present structures.)

Tenure in this structure might simply mean eligibility to serve on programs but not a university obligation to maintain full salary for those not on programs. The group leaders' budgets could be used for salary to tenured staff not fully utilized by programs.

This structure may appear to add much administration to the university activities. Yet, this may not be so. The structure aims to delineate objectives of current activities and to ensure that they are done well. Thus, if the university were doing its job effectively now, no new staff would have to be added, although job descriptions would be changed. The structure might require appointing several people to monitor the quality of instruction. A group, with significant authority, whose primary responsibility is instruction, may be just what universities need.

The advantages of this structure can be summarized as follows: the structure gives direct accountability for both graduate and undergraduate teaching. It follows the functions within the university. It clarifies choices, e.g., the structure shows how the university might go about augmenting an undergraduate computer science program and diminishing graduate work in electrical engineering. Such decisions might be harder to implement in a departmental structure. The project structure also increases faculty choice of allocation of effort and thus makes faculty members more responsible for their professional lives. It allows a faculty member with cross-departmental interests to bargain directly with program managers. The structure causes group leaders (department chairman) to maintain a mix of professors, some who excel in each of the roles required of faculty. It gives group leaders a less ambiguous role than department chairmen--that of a representative or leader of a scholarly discipline.

We understand several institutions, including Rensellaer Polytechnic Institute, and Southern Methodist University have recently implemented project-like organizational structures.

(3) This recommendation meets partly the size obstacle as well as the departmental one because it clarifies responsibilities and shortens the chain of command.

We recommend that the academic administration work with department chairmen to modify the departmental role to reflect college and university-wide concerns.

We further recommend that the academic administration work with nonacademic administrators so that nonacademic units also contribute optimally to solving college and university-wide concerns.

(4) We see a need for an increased awareness of instructional problems at upper levels of both academic and nonacademic administration and, conversely, a need for an increased awareness of administrative problems by faculty. Our recommendations here has several parts.

(a) We recommend that nonacademic administration be encouraged to take courses at the university (even in fields not directly related to their job).

(b) We recommend the expertise of nonacademic administration, e.g., plant engineers, research workers, accountants, computer laboratory staff member , be used in the classroom.

(c) We recommend that academic administrators be encouraged to teach.

(d) We recommend close communications between the faculty and the business staff, for example, through seminars given by nonacademic officers for faculty.

Some of these recommendations are being implemented. Many colleges allow staff members to take job-related courses. The University of Michigan and many other schools involve members of research laboratories in instruction. At California Polytechnic State University in San Luis Obispo, any staff member can take any course for credit without fee. Nearly every academic administrator at Princeton teaches every semester. At Brown, the Vice President for University Relations conducts a lecture series on development (i.e., fund raising).

(5) We recommend that organizational modifications be made to foster faculty trades between campuses and industry or government laboratories.

Most existing research laboratories associated with universities can handle this task with no difficulty. This recommendation is related to recommendations of Chapters 4 and 5.

(6) We recommend studies on the influence of size on administrative structures and, where warranted, the reorganization of large university systems.

We are aware of only one study of the size of universities [6] and it does not address the issue of what size structure is most responsive to needs.

(7) We recommend that institutional channels be established for faculty presentation of ideas for change in teaching, research, or administration, to the highest policy-making body of the administration.

This channel might consist of personal presentation and explanation of the proposal to the board accompanied by a written description. At some later date, the policy board would be required to publicly respond to the proposal. (This process could be thought of as analogous to the grievance procedure except that is is change rather than grievance motivated.)

This recommendation formalizes an opportunity available to faculty at nearly every college and university. We feel that formalizing and publicizing it encourages its use.

Several universities, Cornell for one, have faculty on their Boards of Trustees. Including faculty in trustee deliberations may not be the most effective way of accomplishing this recommendation. Faculty trustees do not seem to consider themselves primarily as representing a faculty constituency. A good discussion of this subject and implicit support for our recommendation above is given in a recent book [7].

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Chapter 9

INFLUENCE OF GOVERNMENTAL, PROFESSIONAL, AND OTHER AGENCIES ON ENGINEERING EDUCATION

This chapter presents some obstacles to engineering education caused by external forces. The roles of state and municipal governments, boards of trustees, faculty unions, accrediting agencies, boards of registration and professional societies, and their influences on the making of educational policy are discussed in this chapter.

A. Legislatures, Coordinating Boards, and Multi-Campus Administrations

Various organizations have recently begun to intrude on the making of educational policy. As war is considered "too important to be left to the generals," so education seems to be considered too important to be left to the professors. Groups that formerly were content to set objectives in most general terms are now beginning to specify operational procedures.

The large portion of the state or municipal budget devoted to higher education seems to demand that the state or municipality governments excercise greater authority in the running of the university. The recent cost squeeze caused by inflation and, in some cases, declining enrollment have accelerated this concern.

Another reason for increasing governmental involvement in the university is the growing lack of confidence in the ability of educational institutions to govern themselves. Campus disruptions of the late 1960's were often blamed on weak administrators and permissive faculty. The claim that through education all of society's ills can be cured has not been substantiated. The value of a college education in the market place is suspect. The public is disenchanted.

As a result, legislative acts have intruded on administrative functions. Statewide boards have been created with broad authority to administrate as well as coordinate. Some state boards have specified faculty teaching loads. Some state university regents have final authority to appoint academic officers, such as the legal counsels, budget officers, deans, provosts, and presidents. And, in many states, such as California, Wisconsin, New York, Rhode Island, and Georgia, large multi-campus universities, governed by off-campus administrators, have arisen. When added to traditional outside influences of accrediting agencies, professional societies and public interest groups, the net effect has been the development of a kind of absentee ownership with all the stresses and conflicts that this entails. The motives may be good, but the net effect is a leveling one which stifles diversity, innovation, and change at a time when these commodities are in short supply.

Private schools may avoid most of these problems, but difficult problems of financing may impose equally stringent, if different, constraints. The students' unrest of the late sixties increased the involvement with school affairs of the trustees of private schools. While their interaction with the school community is welcome, there is concern that their involvement may degenerate into outright intrusion in the day-to-day operation of the school.

We, therefore, recommend that legislatures, coordinating boards, multi-campus administrations, and boards of trustees confine their activities to broad policy questions and coordination and stay out of local administration.

We recognize, however, that an on-going dialogue between the school community and the state boards or the trustees is a healthy one. In fact, we even welcome an "adversary" process so that they can monitor the performance of the profession as well as the academic institution.

B. Faculty Unionization

Ever since the City University of New York opted for faculty union and collective bargaining in December 1968, unionism has spread across the country and is now established at several academic institutions, e.g., State University of New York, University of Rhode Island, Wayne State University, Oakland University. It is reasonable to expect that unionizing activity will be further spurred by inflation and the gloomy economic picture. It is doubtful, however, that unionism will become universal in American higher education at any early date [1].

Although the gains through faculty unionism have not been conclusively assessed in its short history, faculty collective bargaining has typically increased salaries and fringe benefits. Salary increases generally have been commensurate with those gained by state civil servants. There has been a trend toward salary parity between faculties of community and state colleges and university faculties. In private schools, across-the-board increases are common outcomes of collective bargaining.

Faculty unionism has other benefits. Unionism may bring increased faculty participation in decision making; it may induce the establishment and formalization of due process and appeals procedure; it may protect faculty rights in such matters as academic freedom, tenure, promotion and retention, and it may provide access to detailed institutional financial data.

Unionization usually comes in response to faculty grievances and is often organized for defensive reasons. To the extent that it democratizes the institution, prevents excessive abuses of power, and makes the administration as well as the faculty more accountable, unionism seems to have accomplished its goals. Unfortunately, the appearance of unionism on the academic horizon has brought repercussions. The prospect of alienation of faculty and administration from one another as a result of the adversary relationship implicit in collective bargaining is serious. Equally grave is intrusion of unionism on institutional management in such matters as budgeting, course scheduling, faculty work loads, faculty productivity, assignment of teaching personnel and the day-to-day operation of the school. No longer can the president and other academic officers fully exercise their leadership roles. The responsibility of the academic institution is thus diffused. An enlarged institutional bureaucracy is automatically generated. Red tape and bureaucratization of procedures is increased. Efficiency of institutional operation drops while the costs of education rises.

In its drive toward academic egalitarianism, faculty collective bargaining through unionism seeks parity between teaching and nonteaching professionals and among faculties of different disciplines and often causes homogenization and standardization of academic institutions, faculties and other personnel and institutional policies. Its general lack of recognition of individual accomplishments usually results in loss of individual freedom and incentive, and its inability to cope with intangibles and ambiguities due to the need of legal documentation and specificity leaves little room for flexibility and plurality which are essential to a viable academic institution.

The engineering profession, as well as engineering faculty, generally oppose faculty unionization. But, in most colleges and universities, engineering faculty is often the minority and, as such, is usually overwhelmed on the issue of faculty unionization. Since unionism is here to stay, we can only hope that it will not degenerate into a destructive zero-sum game. Where unions or other organizations are recognized as legal bargaining agents, both faculties and administration should endeavor to conduct their negotiations in an atmosphere that will enhance rather than destroy the basic educational values which they both represent. Unionization could result in a postive-sum game if both the administration and the union work toward protecting the interests of students and the academic community at large.

C. Accreditation Agencies

It is our position that engineering education occupies a much narrower band of the total spectrum of technically oriented education than is desirable and that even within that band there is a lack of diversity. Of the many factors which contribute to this uniformity, the accreditation process, particularly that by ECPD, is a major factor. Two sets of criteria, one which relates to faculty quality and the other to curriculum content, have contributed most.

In its drive to improve quality, ECPD has helped to insure that the research Ph.D. becomes a virtually necessary condition to admission to the fraternity of engineering faculty. When it is observed that the top 12 universities produce 85% of the Ph.D.'s (see Appendix 1), it is not surprising that a certain homogeneity of engineering faculty with regard to background and point of view results. It is common and understandable for a faculty member to copy the way he was taught in teaching others. The result is that nearly all engineering programs are very much like those few which supply the instructors.

The general uniformity in course content, course sequencing, and even time sequencing of courses in engineering programs are, to a very large extent, attributed to the effect of ECPD criteria on curriculum content. Some of the large prestigious schools which can afford to break out of this lockstep are handicapped by faculty inertia and attitude. The majority of the schools, including those smaller ones with the least faculty inertia, however, cannot afford to get out of line, for fear of not being accepted. Thus, the ECPD criteria have inadvertently contributed to the present narrow definition of engineering education. It is true that the criteria permit more flexibility than, in fact, has occurred. But, it is only natural for engineering schools to play safe and copy programs that have been successfully accredited.

ECPD, since its inception over 40 years ago, has had as its major purpose, the accreditation of engineering curricula. Over the years, criteria which were first meant to evaluate, have become an end in themselves. The original intent of safeguarding quality has now deteriorated into a numbers game. The curricular content for an accreditable program has been quantified; the criteria are finely delineated and translated into a formula. Within the formula, there are specified credit requirements for each category of subject matters. Quantitative standards are imposed. Deviation from such a norm, for whatever purpose, is frowned upon and often not acceptable.

The personal whims and biases of the accreditation team or the visiting committee often are the bases of evaluation. Instead of objectively evaluating the quality of a curriculum, the team often spends its time nit-picking. A private college in the east in its last accreditation a few years ago was criticized for numbering "engineering economy" with a mechanical engineering label. Another university, on the West Coast, in its recent accreditation, was similarly criticized for labeling "thermodynamics" with a mechanical engineering numbering system. Courses and programs which are similar or identical to the accreditation team members' parent institutions are praised. Courses and programs which depart from the traditional are looked upon critically.

It may be construed that compliance with "the book" is the rule of the game, and conformance with traditional modes is the name of the game. In a recent accreditation at a Big Ten university, the visiting committee was highly critical of an open-ended program which specifies only broad categorical requirements and allows students freedom to work within those general constraints. Although the committee, in checking through the records of the past graduates, could find no discrepancies between the course work and the ECPD requirements, it recommended only partial accreditation of the program claiming that there was no assurance that the procedure would be strictly adhered to in the future. According to the school official, the program is at least equal to the other accredited programs within the institution in terms of technical depth, breadth, and rigor.

In another instance on the West Coast, a prestigious university lost accreditation of a general engineering program which is cross departmental in nature. The program is innovative and as rigorous as other programs in the school. It is currently not accredited by ECPD but is well subscribed by students and the students are in great demand in industry.

While ECPD has understandably been careful not to survey opinion of its accreditation activities, such opinion is all too easy to find at any meeting of engineering educators. The essence of this opinion is that new programs or curricula are acceptable to ECPD only if they look like old curricula. The much vaunted ECPD standards have become roadblocks to diversification, innovation, and change. Unless drastic changes are made, ECPD will soon outlive its usefulness.

If the ECPD criteria are to be deplored for the extent to which they now encourage conformity at a time the profession needs diversity, then prospects for the future are even worse. ECPD has compounded an already bad system by introducing a new level of advanced accreditations which accentuates evils of the earlier process. Essentially covering five-year programs, the advanced level is distinguished from the basic level (the well-known four-year criteria) only by quantitative specification of course and program content. Thus, it extends the basic weakness of the basic criteria into a fifth year.

If ECPD is to continue its accreditation role, we recommend that

(1) ECPD more closely follow its guidelines on accreditation criteria which, according to the ECPD 41st Annual Report, "must be under continual examination and change to accommodate for changes in engineering education." [2].

(2) ECPD set only broad general criteria for basic level accreditation for engineering programs without specifying individual courses, course sequences, and time sequencing of courses.

(3) ECPD embrace innovation in engineering education and grant engineering schools "licenses to experiment" with nontraditional well-planned programs.

(4) ECPD reverse its policy and accredit programs that are contiguous to engineering.

(5) ECPD accredit advanced-level programs based on basic-level accreditation criteria with thirty (30) additional semester hours of course work beyond the baccalaureate requirements of which at least half must be taken in advanced level courses in engineering.

(6) ECPD select with greater prudence visiting committee members who comprise a broad spectrum of the profession, including academic and practicing professionals.

(7) ECPD establish a procedure by which representatives of the visiting committee agree to meet and confer with

representatives of the accrediting program on matters related to the recommendations of the visiting committee, at the request of the latter, in the presence of a mutually agreed to third party, and before the findings and recommendations of the visiting committee are submitted for final action by the Board of Directors of ECPD.

There is also the problem of different agencies of accreditation within engineering itself. The National Commission on Accrediting recognizes ECPD for accrediting programs in engineering and engineering technology, while authorizing NAIT (National Association of Industrial Technology) to accredit industrial technology programs. It seems natural for ECPD and NAIT to work together in common areas for coordination and cooperation in accrediting activities in the separate areas of industrial technology and engineering technology. Unfortunately, they do not, and the prospect is not even in sight [3].

We therefore urge the National Commission on Accrediting to consolidate the accreditation of programs in engineering, engineering technology, and industrial technology under one agency.

D. Professional Registration

We believe that most engineers, particularly those who work at the interface with the society, should be registered, although we recognize that not all engineers need be. Many of the 30% of engineers who are registered are civil engineers. One reason that most other engineers are not registered is that industries do not usually require registration of their engineers.

Currently, registration is done on a statewide basis. Each state has its own Board of Registration of Professional Engineers and makes its own policy. The National Council of Engineering Examiners (NCEE), comprising the boards of all fifty states and the five federal jurisdictions (Guam, Puerto Rico, Virgin Islands, Canal Zone, and Washington, D.C.), services the various boards with their problems on registration, transfer, and related matters, and provides national examinations for both the EIT (Engineer in Training) and Professional registrations. Each state has the option of constructing its own examinations or adopting the national examinations in one or both categories. As of now, only four states (Colorado, Illinois, New Jersey, and Pennsylvania) have not yet adopted the national examinations. Five years ago, about 40 states used NCEE's EIT examinations, and about 35 adopted NCEE's Professional examinations. Over the last three years, in particular, the trend toward uniformity through national examinations has accelerated.

We thus urge that uniform national examinations, both for EIT and Professional registrations, prepared by NCEE but administered by individual state boards, be the ultimate goal. We also recommend that registration in one state be recognized by and transferrable to any other state.

Each state may require additional examinations to meet its special needs. For instance, California may require a registered civil engineer to know seismology. This supplementary level of registration should be minimized, however, so that there is truly a unified national registration criterion and procedure.

Current requirements of qualifications for registration vary from state to state, from practically no professional experience in California to four years of professional experience in New York to qualify for the EIT examination, and from six years of acceptable professional experience in California to eight years of professional experience in New York, to be eligible for Professional registration. EIT passage is always a prerequisite to examination for Professional registration. Graduation from a ECPD accredited cirriculum is considered equivalent to four years of professional experience, while a baccalaureate degree from a non-ECPD accredited program counts only as two years of professional experience.

We definitely favor standardized requirements and criteria for the two levels of examinations.

We recommend that four years of acceptable professional experience and a written examination on engineering fundamentals be required for EIT registration, and that four additional years of professional practice and the passing of a written examination on the specialized professional area of engineering be required for Professional registration.

We contend that formal education in engineering is one way of acquiring experience. Thus,

we recommend that an earned baccalaureate degree in engineering be equivalent to four years of professional experience and that six months before graduation, a student should be eligible to take the EIT examination. Formal education beyond the baccalaureate degree should be accepted as professional experience on a one-to-one basis, up to a maximum of two years.

Thus, a Ph.D. degree should count at most as two years of professional experience.

Most of these recommendations are consistent with NCEE's model, which many states are adopting.

Keeping up with the state of the art is very important in engineering. It gains added significance particularly when we realize that life-long learning is crucial to professional vitality.

We, therefore, recommend that a professional engineer be registered for a period of only six years and extension of registration can be made through reexamination at the professional level or formal coursework in the specialized area of the profession.

E. Professional Societies

Professional societies in promoting their respective disciplines have indirectly compartmentalized engineers and solidified the professional departments in engineering schools as separate and distinct units of operations. This isolation of departments invariably brings about "empire" building, which further causes engineering to lose its catholicity.

There are two umbrella organizations, ECPD and EJC (Engineering Joint Council), to which all professional societies belong. ECPD deals with those professional aspects of engineering which are mostly school oriented, whereas EJC concerns itself mostly with the professional life and other inter-society activities. While both organizations serve the profession fairly well, a single organization that can speak for the engineering profession, just as AMA and ABA speak for the medical and the legal professions, respectively, would definitely be advantageous. Attempts in the past to consolidate ECPD and EJC into a single unit, have not been successful.

We strongly urge that the directors of ECPD and EJC make concerted efforts to merge ECPD and EJC so that the unified organization can be the mace bearer for the engineering profession.

Engineering as a profession, has definitely earned its place under the sun. Yet, the public is quite uninformed about engineering. When public opinion proclaims "scientific success" when the rocket goes up and "engineering failure" when it does not, we recognize the need of increasing technological literacy. This job can best be done through a single national organization, such as the one recommended above. The professional societies, through this national organization, can help to promote the interests of engineering education.

References for Chapter 9

1. The Management and Financing of Colleges, Committee for Economic Development, Oct 1973, pp. 59-60.

2. Engineers' Council for Professional Development, 41st Annual Report - Year Ending Sep 30, 1973.

3. Report of the Accreditation Coordination Committee, 41st Annual Report of ECPD, p. 18.

Appendix 1: TRENDS IN ENGINEERING EDUCATION

Outline

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C-2

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Appendix 1

TRENDS IN ENGINEERING EDUCATION

A. Inside Schools of Engineering

1. Students

a. Changing Career Choices

After World War II, university enrollment burgeoned with the help of returning servicemen. The campus embraced a large contingent of mature students. For the first time, the married student belonged. This generation of students, children of the great depression whose adolescence was lived in wartime austerity and physical danger, had well defined, generally financial goals. By the late fifties and early sixties, student aspirations had modified. High starting salaries lost some of their magnetism. Graduates, especially from engineering and business, seemed to expect continuing long-term benefits from their employment; benefits such as job stability and advancement, insurance, stock option, and retirement plans.

The students of the 1960's, untouched by depression or major popular war, and mostly the children of white middle and upper income parents, seemed less impressed by the lure of financial gain as a prize for education. Some students dropped out and became the nucleus of the counter-culture. Others remained within the system, but in adversary roles.

Campuses changed during this period. Students refused to be treated as adolescents. Institutions relinquished their long-held in loco parentis roles. Faculty and administrations were held accountable for their actions. New student-centered programs emerged. A desire for open learning emerged, perhaps more visible in primary and secondary schools than in the universities. Many of these changes were the result of legislative action, but agitation for them began with student activism.

During the first half of the present decade, further changes in the student are discernable. Engineering enrollment has declined. This decline is probably due to many factors--depressed employment, a perceived lack of relevance of technology, and unsatisfactory preparation and counselling in secondary school. Student selection of "people-oriented" curricula (psychology, sociology, architecture, etc.) remains high. Enrollment in the professional schools--medicine, law, business--remains at or near capacity. Throughout the university is seen the student plea for more "how to" courses such as drafting, welding, and masonry--sometimes viewed by educators as more appropriate to technology than to engineering. This action might be attributed to students' desires for enhanced job opportunity; however, it may also be due to the desire for expression of self.

With only one exception, careers currently gaining favor for both men and women are either perceived as having a heavy social significance content or allowing for an expression of self. The careers gaining favor from 1968-1969 to 1972-1973 and the percentage change are [1]:

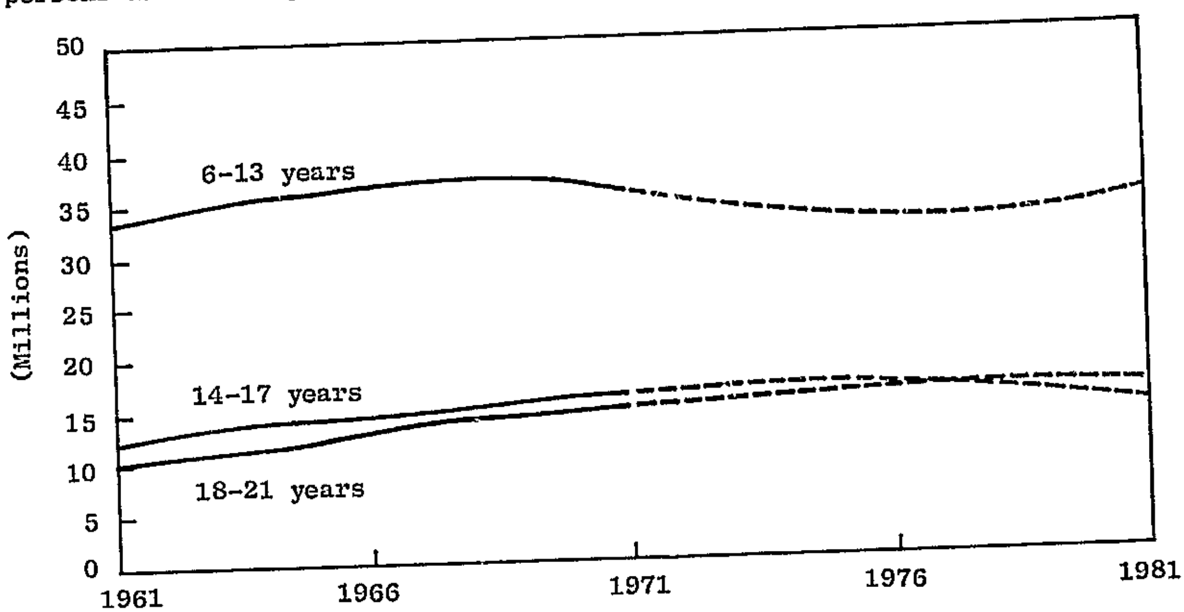
Artists, including performers	4.2-5.2%
Doctor	5.6-7.9%
Farmer, Forester	2.9-4.8%
Health professional	2.8-4.6%
Lawyer	5.5-7.1%

Careers losing favor during this same period are:

Businessman	17.5-13.4%
College teacher	1.3-0.7%
School teacher	12.7-5.7%
Engineer	14.6-9.6%
Research scientist	3.8-3.1%

b. Student Population Trends

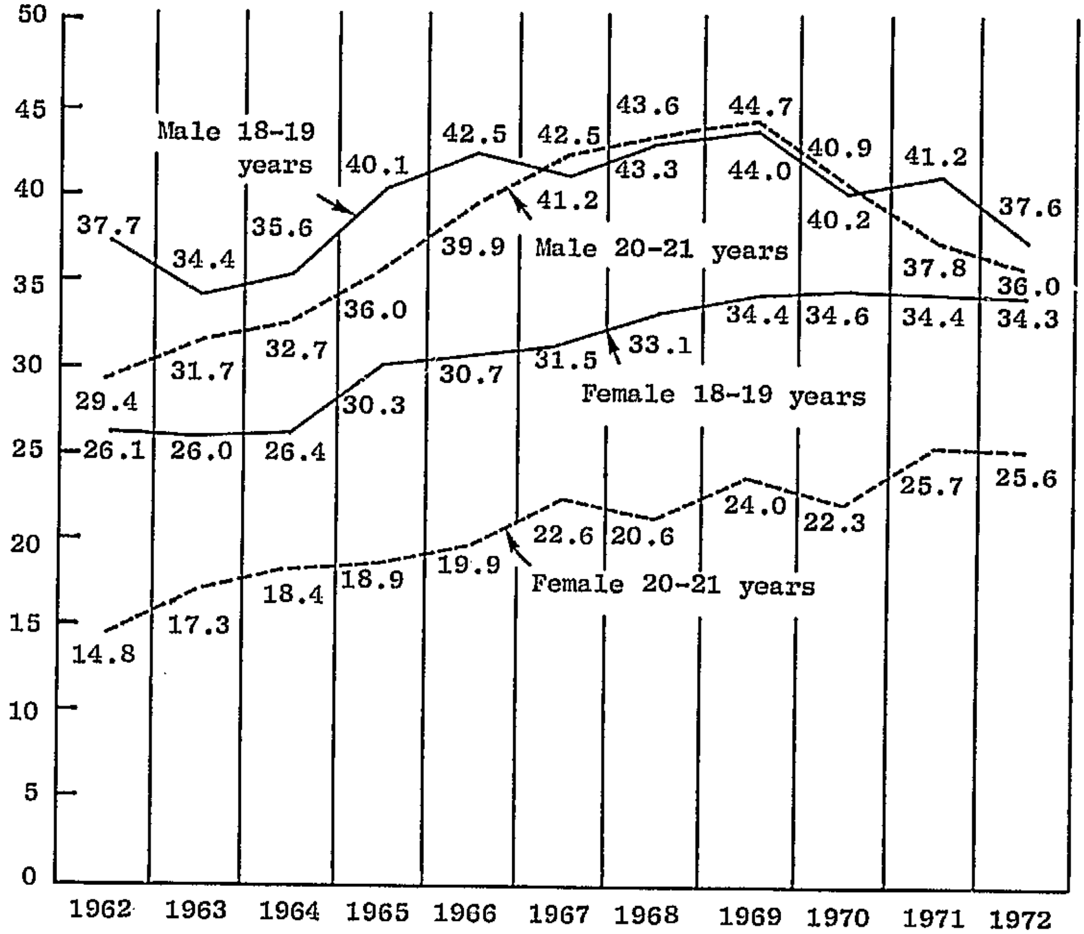
That some significant changes are in store for education, even engineering education, is apparent. For the immediate future, the supply of students for any post-secondary education will remain constant or actually decline, as shown on the graph of school age population. Despite the dashed line, the curve is not tentative but real, since these persons are already born and their numbers are known accurately.



Source: U.S. Offi › of Education, "Projections of Educational Statistics to 1.. ı-82."

Figure 2. SCHOOL-AGE POPULATION: UNITED STATES, OCTOBER 1961 TO 1981 [2].

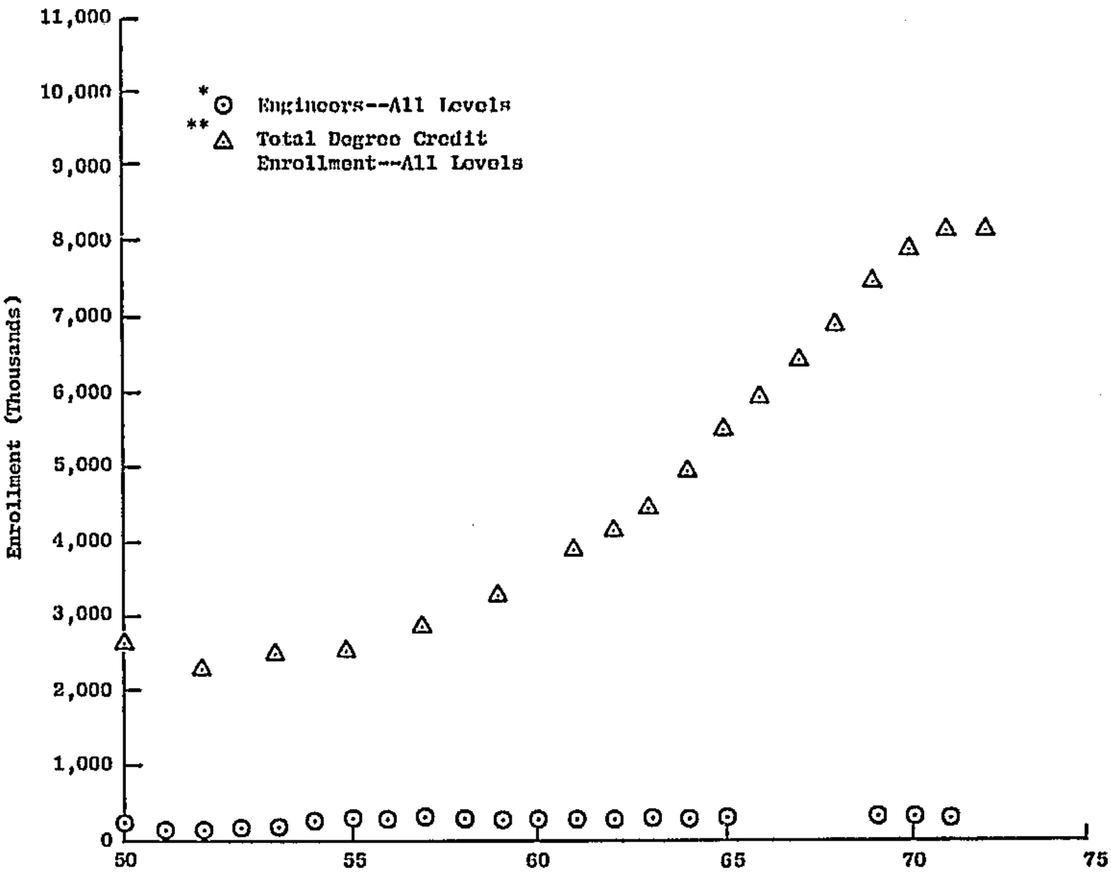
Apparently, the lure of college is less compelling now than it was five years ago. A lower percentage of men elect the college experience. However, the number of women in college is growing steadily, as shown in Figure 3.



Source: U.S. Bureau of the Census.

Figure 3. RATES OF COLLEGE ATTENDANCE, BY SEX [3].

Three graphs present trends in engineering enrollment as compared to total enrollment in higher education. Figure 4 shows engineering and total enrollment from 1949 through 1971. Engineering enrollment from 1949 to 1957-1958 fluctuated generally the same as overall enrollment and represented approximately 8-11% of total enrollment. From 1957-1958 until 1969, engineering enrollment increased to a peak in 1969 of 321,471 students and then declined to 292,854 students in 1971, less than 4% of the total enrollment. This trend ha continued to the present with engineering attracting even fewer students each year.



*Source: U.S. Department of Health, Education and Welfare, Office of Education, "Engineering Degrees (64-65), Enrollments (Fall 1965); and Engineering Manpower Commission of Engineers Joint Council.

**Source: Standard Education Almanac 1973/74, Academic Media, Orange, N.J.

Figure 4. ENGINEERING ENROLLMENT--TOTAL ENROLLMENT [4].

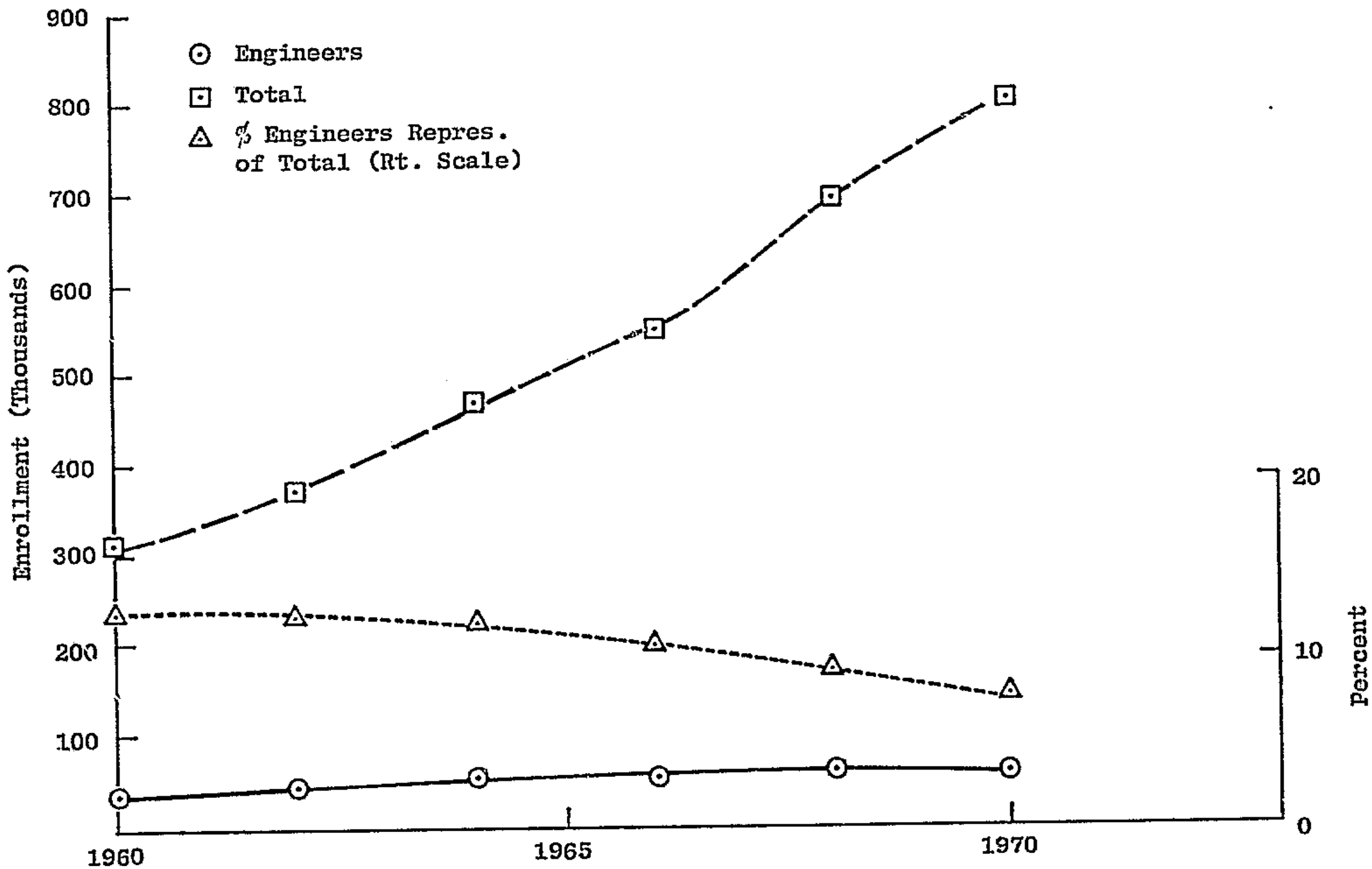
Figure 5 is a plot of engineering enrollment for master's and doctor's programs versus total enrollment for master's and doctor's programs for the period 1960 to 1970. The percent of the total that engineering enrollment represents is also plotted. Total enrollment has increased almost 300% in this time frame, while engineering enrollment has not quite doubled. The percent that engineering enrollment represents of the total graduate level enrollment has dropped from approximately 11.5% in 1960 to less than 8% in 1970.

Figure 6 is a plot of earned bachelors and first professional degrees divided into three parts--engineering, "other science," and all other disciplines--for 1959-1960 through 1969-1970 and then estimated or forecast to 1981. Although earned engineering degrees have increased significantly (by about 15,000) from 1959-1960 to 1969-1970, the percentage these represent of the total has dropped drastically from approximately 13% to 8%. During this same period, the number of earned "other science" degrees have experienced a less severe percentage decline from over 27% to about 22%. Combined "other science" and engineering shows a percentage decline compared to the "all other" category from over 40% to approximately 30%.

An important factor in student population is the rapid growth of engineering technology programs. Accurate historical data are not available, but it is known that only a handful of associate and bachelor's degrees in engineering technology were awarded 15 to 20 years ago. By 1971-1972, the number of degrees awarded in engineering technology rose to 22,578 associate degrees and 5,487 bachelor's degrees compared to 44,190 engineering bachelor's degrees [5]. Enrollments were 149,251 in associate degree and 27,628 in baccalaureate technology programs compared to 208,876 in engineering baccalaureate programs [6].

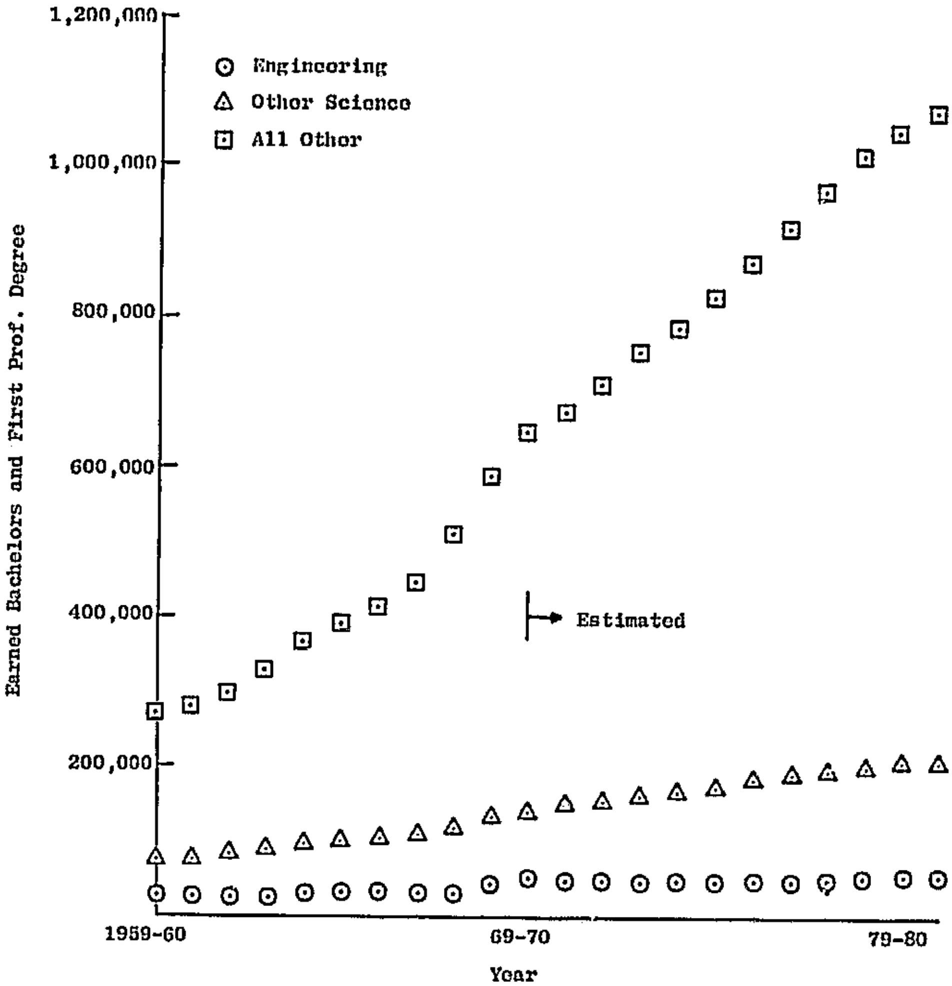
A recent article [7] identifies 95 institutions offering baccalaureate programs in engineering technology. Since some established institutions known to be offering these degrees are missing from this list and others are known to be adding such programs, it is likely that 125-150 institutions soon will be supplying four-year technology graduates. This is about one third as many as are offering engineering programs.

As already mentioned, many jobs formerly filled by engineering graduates are now filled by technology graduates. In many states, four-year technology graduates qualify for registration as professional engineers. In many, perhaps most, cases, the job title industry gives to these graduates is an engineering title. A survey of students enrolled in technology programs shows that many would be qualified to enter engineering programs. Others are qualified in terms of ability but not background, i.e., technology programs admit students with less complete mathematics and science backgrounds from high school. Technology programs have significantly affected engineering enrollments and engineering employment, and since enrollment in these programs has grown while engineering enrollments have declined, the future effect will be even greater.



Source: U.S. Department of Health, Education and Welfare, Office of Education, Circulars on "Students Enrolled for Advanced Degrees."

Figure 5. ENROLLMENT FOR MASTER'S AND DOCTOR'S DEGREES--U.S. AND OUTLYING [8].



Source: U.S. Department of Health, Education and Welfare, Office of Educational Publications, "Earned Degrees Conferred by

Figure 6. EARNED BACHELOR'S AND FIRST-PROFESSIONAL DEGREES--UNITED STATES [9].

c. New Program Directions

As some specialties wane, others emerge. New technologies may be expected to attract students from a wider group of society than most engineering schools have traditionally attracted. Characteristic of these new technologies--perhaps to be known as "soft or social technologies"--is their primary concern for people or the environment rather than things, their concern for decreased energy requirements, and their willingness to learn from and work with other disciplines, technology-based or not. Whether these emerging technologies fly the flag of engineering is a question yet to be decided.

Two groups in particular have been underrepresented among engineering students--ethnic minorities and women.

Four ethnic minorities--blacks, Chicanos (Mexican-Americans), Puerto Ricans, and American Indians--are substantially underrepresented. A 1974 study by the Sloan Foundation [10] found that in 1970 these minorities comprized only 2.8% of U.S. engineers, although they represented 14.4% of the U.S. population. The study estimated that in 1973 only 5.1% of freshmen enrolled in U.S. engineering schools belonged to these four minorities.

The reasons for underrepresentation of these four minorities vary, although all four groups are generally affected by poorer elementary and secondary education than most whites receive. The pool of blacks who attend college is proportionately larger than for the other three groups. Engineering schools can hope to attract students from the pool of black college students as well as to attract them by providing better secondary education. Blacks attend community colleges in higher proportions than whites and have a higher dropout rate. Chicanos and Puerto Ricans lag both blacks and whites throughout their education. A major problem is the lack of bilingual education in the critical early years. American Indians also suffer from the lack of bilingual education and have the additional problem of attending schools on Indian reservations that are controlled by the Bureau of Indian Affairs (BIA) instead of by the Indians themselves. Only about 13% of Indian students who enter BIA high schools graduate from college.

The Sloan Foundation report recommended efforts to increase the representation of these four ethnic minority groups in engineering to about 18% of the profession in the 1980's when these groups will be about 18% of the population. Their recommendations included increased financial support of minority students, added guidance, orientation, and tutorial programs, and improvements in elementary and secondary education, especially in bilingual programs.

Women have historically comprised about 1% of the engineering profession and a similar proportion in engineering schools [11]. Recently, there has been an increase in the numbers of women entering engineering schools that parallels the increase in women entering medicine, law, business, and other traditionally masculine professions. At least one engineering school reported that women comprised about 10% of its undergraduate engineering enrollment in 1973-1974. It is too early to know how the increased interest of engineering schools in recruiting women will affect their entrance into the profession.

One bright spot in the picture for women engineering students is that they tend to receive graduate degrees in engineering in greater percentages than other special groups. For several years women and blacks have earned about the same number of B.S. degrees in engineering, but women have earned two to five times as many M.S. degrees per year, and three to ten times as many Ph.D.'s per year.

Women who wish to enter engineering are still discriminated against in admissions by the service academies, but are relatively free to enter the other 98% of U.S. engineering schools. They have more opportunities today than ever before in engineering because of federal affirmative action requirements and because of the decisions of engineering schools and professional societies to encourage women to enter engineering.

2. Instruction

Faculty members function in multiple roles. Basically, of course, they serve as instructors, however, this may no longer be their prime function in many institutions. Research, student advisement, committee assignments, and other such activities, constitute over 50% of faculty members' time in many universities. Salaries of faculty represent an average of one third of educational and general expenditures (less organized research), two thirds of expenditure for instruction and departmental research, and approximately 22% of total expenditures.

An MIT report [12] states that the student-faculty ratio appears to have fallen 19% in the period 1969-1972 or from 1 faculty member for every 10.4 undergraduates in fall 1969 to 1 faculty member for every 8.4 undergraduates in the fall 1972.

The trend in student faculty ratio from 1955 through 1967 is as follows [13]:

(1) The ratio of full-time-equivalent students to full-time-equivalent faculty in four-year public universities increased from 15.4 in 1955 to 20.1 in 1967.

(2) The ratio in four-year private universities increased from 14.2 in 1955 to 16.2 in 1967.

These are weighted ratios, weighting graduate enrollment on a 3 to 1 basis. The trend in teaching loads indicates that in private and public research universities, in 1931-1932 faculty members spent about 15 hours per week in classes, while in 1969, the number was around 6 [14,15]. Part of the reduction in teaching loads can be attributed to an increase in the ratio of junior instructors (teaching assistants) to senior faculty. This ratio increased from 0.13 in 1955 in public universities to 0.21 in 1967-1968. The corresponding ratios for private universities were 0.20 both in 1955 and in 1967-1968 [16].

The Carnegie Report, "The More Effective Use of Resources," quoted a recent survey that indicated faculty members work an average of 50 hours per week. Studies at Claremont and University of California referenced in the report, determined the distribution of faculty time as follows:

(1) At Claremont Colleges the average hours and percentages of time spent by faculty on various activities are: instruction--33 hours and 60%; administrative activities--5 hours and 9%; research activities--12 hours and 22%; other activities--5 hours and 9%, for a total of 55 hours.

(2) The same figures for all faculties at the University of California are: instruction--30 hours and 50%; administrative activities--7 hours and 12%; research activities--19 hours and 32%; other activities--4 hours and 7%, for a total of 60 hours.

State legislatures recently have tended to mandate teaching loads in public institutions due to concern over outside activities of faculty members. Private consulting has always concerned both taxpayers and administrators. The percentage of faculty in research universities with 11 or more hours of consulting is 16.1 for public and 22.7 for private universities. These figures indicate there is not as much abuse of outside activities as generally assumed by legislators and the public. Most universities limit consulting to one day per week.

The majority of engineering faculty members received their graduate training at a relatively small number of universities [17] (see Table 1). The survey on which this table is based was done in 1958 and considered all disciplines. However, data from later years are consistent with the 1958 data. Berelson commented on the high degree of stability at the top among universities over time. Since the major producers of engineering Ph.D.'s are included among the top 22 universities of the table, data for engineering faculty should not be substantially different.

The age distribution of faculty, the distribution among the three professional ranks, and highest degree held information, is visually presented in Figure 7. In 1970, over 40,000 engineers were employed by educational institutions [18]. In April 1972, over 70% of the faculty at 28% of the public two-year colleges reviewed were tenured [18]. Officials at the University of Colorado are predicting 90% tenure if present policies are continued. Many other schools are approaching the 80% tenured mark.

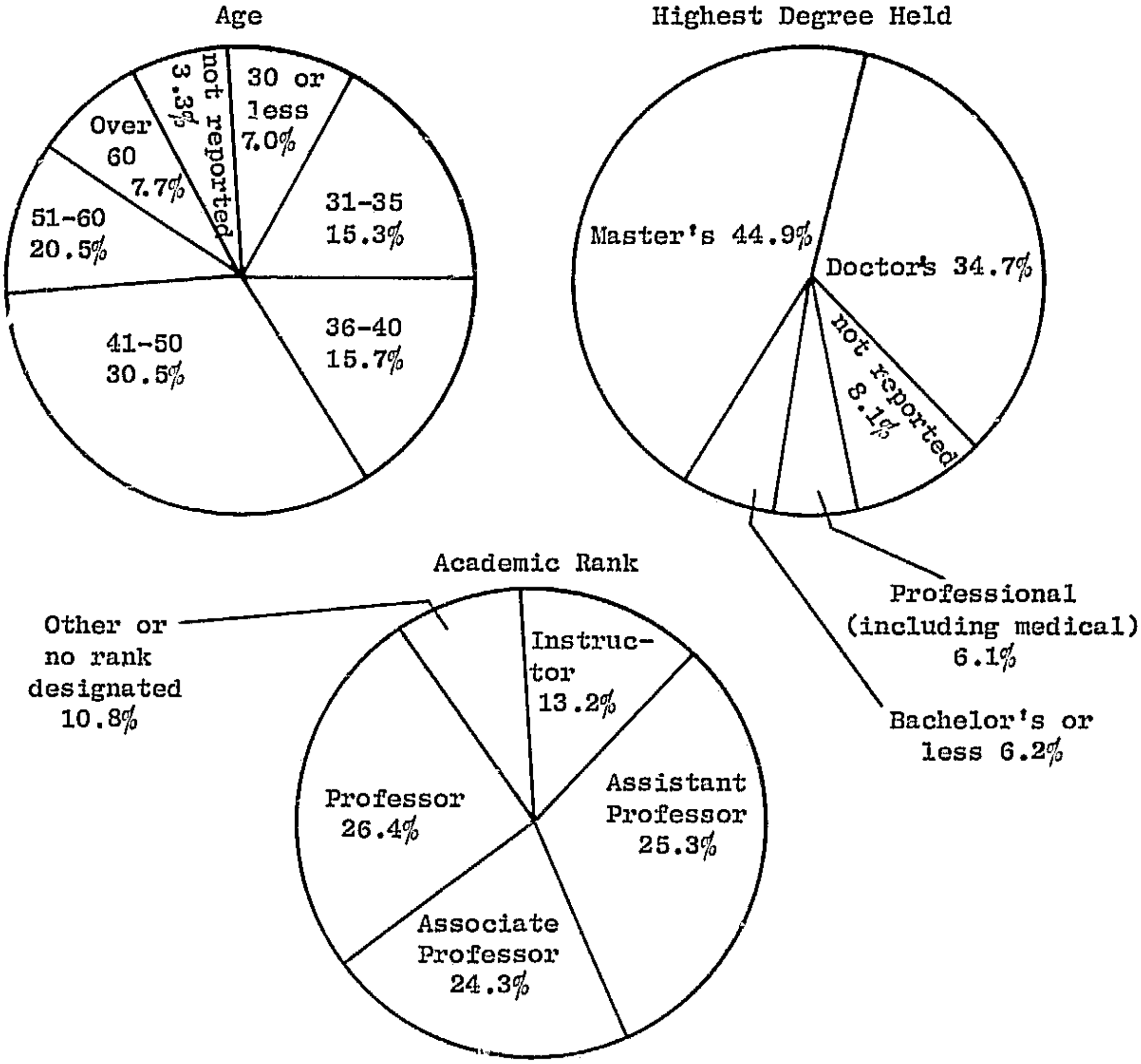
Unionization of faculty members is growing. By November 1972 there were 80,000 faculty members in unions as opposed to only 10,000 in 1968. Younger faculty members generally appear more oriented to unions than older faculty.

Table 1

SOURCE OF FACULTY DEGREES

Received Highest Earned Degree From:	Present Faculties of:*						
	Top 12 Universities	Next 10 Universities	Other AGS, Plus	Other Universities	Best Colleges	Better Colleges	Other Colleges
Top 12 Universities	85%	47%	44%	31%	44%	33%	21%
Next 10 Universities	9	38	13	15	19	16	11
Other AGS, Plus	2	8	31	17	15	19	23
Other Universities	1	6	7	28	7	12	23
Other							
Total number of cases (= 100%)	187	253	297	274	261	354	347
In-breeding (i.e., highest earned degree from own institution)	47	27	20	15	5	6	4

*These data were secured primarily from the faculty lists in college and university catalogues. Incidentally, just as William James implied nearly sixty years ago, it is the lesser institutions that are quicker to list the degrees of their faculty members.



Source: American Council on Education, Research Report Vol. 8, No. 2, Teaching Faculty in Academe: 1972-73.

Figure 7. SELECTED CHARACTERISTICS OF TEACHING FACULTY IN COLLEGES AND UNIVERSITIES: UNITED STATES, 1972-1973.

3. Programs and Curricula

a. Programs in Engineering

Formal education for engineering in the United States began during the early 19th century with establishment of curricula at the United States Military Academy in 1802. Civil engineering, mechanical engineering, electrical engineering, mining and metallurgy, chemical engineering, industrial, agricultural, sanitary, and such specialties as ceramic engineering, textile engineering, nuclear engineering, and aerospace engineering have followed, some appearing only recently. In the last decade or so, cross disciplinary programs such as biomedical engineering, environmental engineering, computer engineering, and systems engineering, have emerged.

Over the past 175 years, engineering education has undergone three major phases of transition [19,20], indistinguishable through the precise boundaries may be.

(1) The Empiricism Phase--transition from apprentice training to formal training and creation of engineering schools (late 19th-20th century).

(2) The Engineering Science Phase--approach engineering education to science and major development of graduate studies in engineering (following World War II).

(3) The Socio-Technical Phase--application of engineering methodologies to a broad spectrum of societal problems; development of interfaces between engineering and all other societal activities (beginning in the middle and late 1960's).

During the last phase, epitomized by the creation of IRRPOS (Interdisciplinary Research Relevant to Problems of Our Society) in 1969, and RANN (Research Applied to National Needs) in 1971 within NSF, engineering research activities are beginning to broaden from those based purely on math and science to those that are "applied" and more socially relevant. Engineering education, too, is beginning to interface more with society at large. More and more programs, research or educational, are directed at the socio-technological interface. In the last five years, for example, foundations such as Sloan and Carnegie have funded the establishment of such multi-disciplinary programs.

The development of interfaces between engineering and other professions, particularly those of humanistic and societal relevance, is the beginning of a new form of liberal education in engineering. Movement toward interfacing engineering with law and the legal profession, with medicine and health care delivery in the U.S., with management and administration, business or governmental, with problems of national concerns and policy, with humanities and social sciences to the extent of establishing a new program in "social engineering," and with a whole host of other professions is beginning to appear upon the scene.

In his study of engineering curricula between 1946-1947 and 1966-1967, Roy [21] observed that in 1947-1947, the curricula of nearly all engineering schools in the U.S. could be represented by like patterns of course specification and credit requirements. This is still true. One reason for this, undoubtedly, is the ECPD requirements for accreditation of basic level engineering curricula. In 1973, 225 of the 280 engineering colleges offered ECPD accredited programs at the baccalaureate level [22]. The specific requirements for these programs are as follows:

(1) Minimum of one full year of math and physical science.

(2) One year of engineering science.

(3) One half year of design.

(4) One half year or more of humanities and social sciences (excluding industrial management, personnel administration, finance, and business).

Table 2 shows the number of accredited programs in each ECPD category of engineering curricula in the United States.

Table 2

CURRICULUM CATEGORIES IN ENGINEERING

Category	Description	Total ECPD Accredited Curricula and Option, 10'73
Aerospace	also includes Aeronautical, Astronautical, and similar titles	59
Agricultural	also includes Irrigation and Drainage	42
Architectural		10
Biomedical	incorporates bioengineering and similar titles	4
Ceramic		14
Chemical		125
Civil	also includes Construction, Soil, Structure, Surveying Transportation, and Urban Systems	174

Table 2

CONTINUED

Category	Description	Total ECPD Accredited Curricula and Option, 10'73
Electrical	also includes Communication, Electronics, Electric Power, Computer, Systems and Control	212
Engineering Sciences	also includes Applied Science, Engineering Mathematics, Engineering Mechanics, Engineering Physics, General Engineering and similar titles, sometimes without the word "engineering"	79
Environmental	also includes Air Resources, Sanitary, Water Resources, and similar titles	25
Geological	also includes Geophysical	20
Industrial	also includes Administrative, Management, Manufacturing, Operations Research, Systems (in a broader context) and similar titles	78
Marine and Naval	also includes Ocean and Naval Architecture	9
Materials, Metallurgical	also includes Welding	66
Mechanical	also includes Energy Conversion, Design Graphics, Fluid and Thermal, and similar titles	180
Mining	also includes Mineral	20
Nuclear		
Petroleum	also includes Natural Gas	
Others	includes Fire Protection, Forestry, Optics, Paper, Textile, etc.	2

Curriculum changes of the past twenty years have required higher levels of accomplishment in mathematics, greater exposure to science, enlarged freedom of choice in humanities and social sciences, a trend toward more engineering sciences and a greater freedom of choice in these subjects, more flexibility in terms of choice of engineering and technical courses, and more elective courses, both designated or undesignated. All these were accomplished simultaneously with a general reduction of credit requirements for the baccalaureate degree. (For example, between 1946-1947 and 1966-1967, the semester credit hour requirements for a baccalaureate degree dropped from 153 to 144 at Tulane, 185 to 139 at Cornell, and 138 to 128 at Michigan.) More recently, many schools have dropped to the 120 to 128 semester hour range. These changes have resulted in the sacrifice of a great amount of applied contact from the traditional engineering curricula.

Courses offered in humanities and social sciences are usually discrete entities designed for majors in the field rather than courses aimed at engineering students. As a result, dissatisfaction with humanities and social sciences of the past has become widespread enough that a movement toward integrating them with the engineering curriculum seems to be occurring [22]. The need for increased emphasis of humanities and social sciences in, and their integration with, the engineering curriculum has also been underscored by the Olmsted Report [23] and the Goshen Report [24]. Innovations in this area have been made at Rensselaer [25], Worcester [26], IIT [27], and Carnegie-Mellon [28].

b. Impact of Educational Technology

Educational technology, in the broad sense, was available before higher education began in the United States. Since the development of digital computers and television, however, startling new uses of technology in education have been proposed. Several systems have been successfully implemented and probably every major institution is using some form of the new technology. Yet, the total impact on higher education has not been highly significant nor the acceptance pervasive [29]. Cost and lack of recognition of a compelling need may explain the evident neglect of these new ways of educational delivery. For more detail on educational technology, see Appendix 3.

c. Programs and Curricula in Engineering Technology

Engineering Technology stresses production and applications. Programs in engineering technology, both at the two-year associate degree level and at the four-year baccalaureate degree level, and both accreditable by ECPD, have grown rapidly, particularly in the last five years. As late as 1967, for example, there were only 2 curricula in Engineering Technology at 1 school, accredited by ECPD at the baccalaureate level and 193 programs at 61 schools at the associate level, whereas in 1973, there were 81 programs at 24 schools and 321 programs at 105 schools, respectively. The number of institutions which offer four-year baccalaureate degree programs in engineering technology was reported to be 95 [30]. In 1971-1972, there were 22,578 associate degrees and 5,487 baccalaureate degrees awarded in engineering technology compared to 44,190 engineering bachelor's degrees awarded in the country. There were 149,251 students in associate degree and 27,628 in baccalaureate degree programs in technology, compared with 208,876 students enrolled in engineering programs. Technology programs will probably continue to increase in the immediate future, due to increased recognition and an improved employment picture.

d. Programs and Curricula in Industrial Technology

Four-year baccalaureate degree programs in industrial technology have appeared in the last fifteen years. While the engineering technology graduates support engineering, the industrial technology program emphasizes production management and operates on the interface between engineering and business administration. In a sense, it fills a need once filled by Industrial Engineering Programs.

The typical industrial technology curriculum contains about 50% mathematics, science, and technical courses, while the engineering technology program has about 70% in these areas. The industrial technology curriculum has several business type courses, much like the four-year engineering curriculum of 20 to 30 years ago. Industrial technology programs are accredited by NAIT (National Association of Industrial Technology).

4. Cost and Finance

a. Income

Every university is a business with substantial capital investments in buildings and land. The administration and the faculty are the management and the workers, respectively. Financing of the universities is much like financing any other large business. Historically public institutions have been supported to a large extent by various levels of government, while the private universities depended more on endowment income, gifts, and tuition.

The sources of income for higher education in 1970-1971 are shown below in millions of dollars.

In 1971-1972, the federal government funding of higher education was 42.5% of the total federal-state contribution. This 42.5% included 20% for veterans benefits [31]. There is a 25 to 30% indirect public subsidy to private universities, because these institutions do not pay property tax and are usually not assessed for local public services. Public institutions are subsidized at more than 30% with tuition covering only 20% of the costs [31].

Figure 8 shows the trend in costs per FTE in public and private institutions. Costs have increased dramatically in the period

Table 3

HIGHER EDUCATION INCOME SOURCES--1970-1971 (MILLIONS OF DOLLARS)

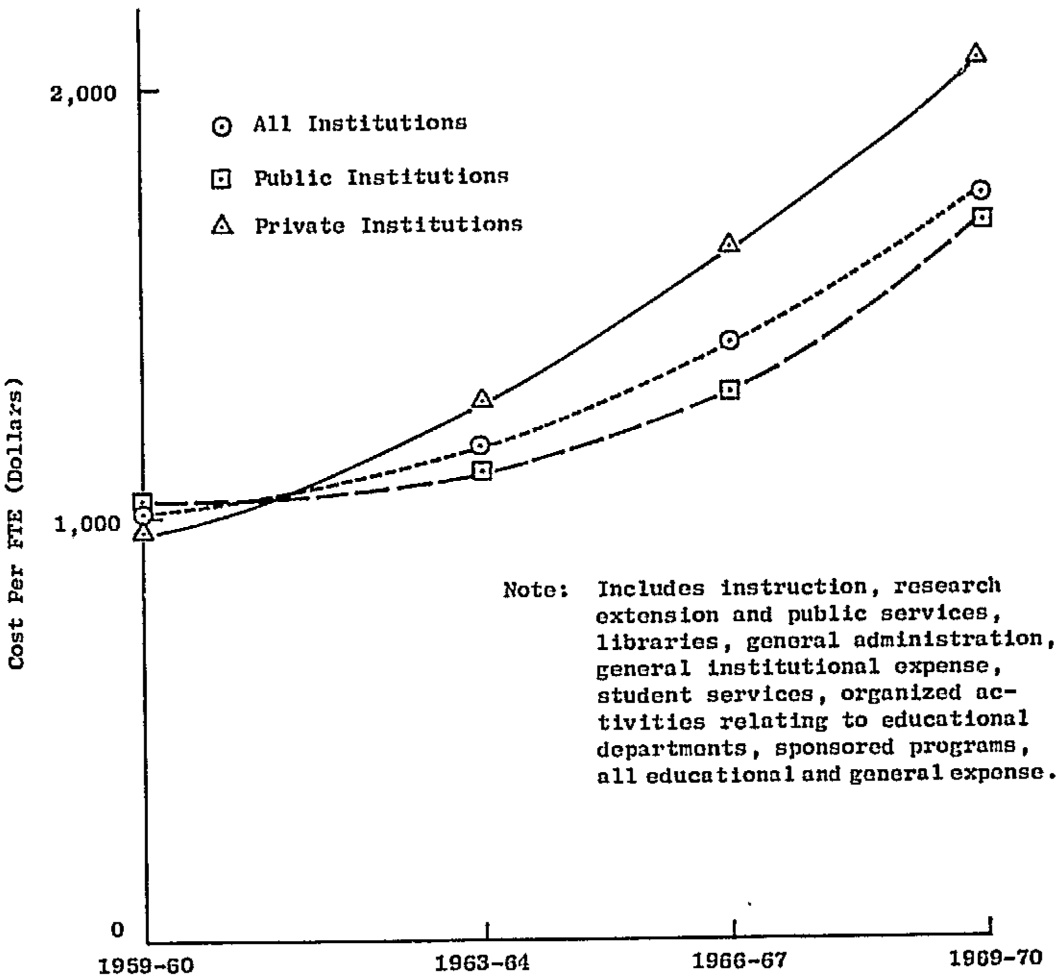
Source	Public Institutions	Private Institutions
State and local	7,494	110
Federal givernment		
(a) research and service	1,180	1,280
(b) other	1,000	330
Tuition and fees	1,887	2,963
Endowment	70	430
Gifts	330	830
Sale of services	105	38
Related activities	1,190	1,120
Student-aid income		
(a) public sources	378	197
(b) private	101	172
Auxiliary enterprise	2,010	1,460
	15,745	8,930

1959-1960 to 1969-1970 with the rate of increase greater than the inflation rate. Private institution costs are going up at a rate even greater than that of public institutions.

Figure 9 presents the weighted annual expenditures per FTE (graduate enrollment is given at weight of three, with one for the undergraduate) for a number of different types of institutions as defined by the Carnegie Commission in "New Students and New Places." Educational and general expense correlates closely with organized research, irrespective of whether the university is research oriented, a comprehensive college or university, a liberal art college, or a two-year institute.

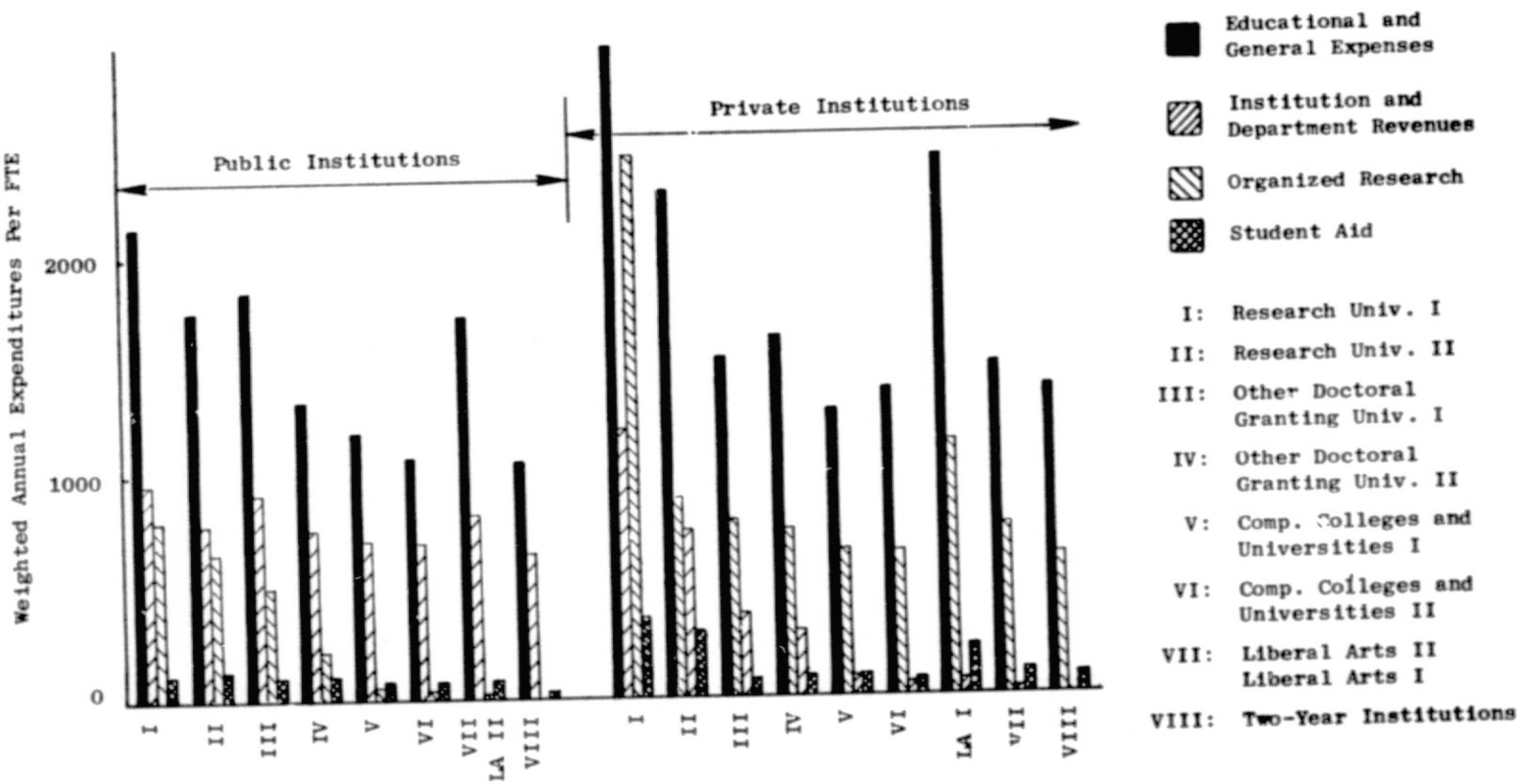
b. Expenditures

Expenditures for higher education have increased continually, especially since World War II, and have almost tripled when expressed as a percentage of the GNP (Gross National Product) during the 15 years from 1955 to 1970, as shown below. Estimated figures for 1980 are also shown as recommended by the Carnegie Commission.



Source: U.S. Office of Education Data.

Figure 8. AVERAGE COSTS PER FTE--HIGHER EDUCATION--1959-1970.



Source: U.S. Office Education Data Adapted by Carnegie Commission Staff.

Figure 9. WEIGHTED ANNUAL EXPENDITURES PER FTE.

Table 4

TOTAL HIGHER EDUCATION EXPENDITURES AND GROSS NATIONAL PRODUCT (BILLIONS OF DOLLARS)

Year	GNP	Total Expenditures	% Expenditures are of GNP
1955	398	3.5	0.88
1960	504	6.3	1.25
1965	635	12.4	1.81
1970	974	24.2	2.48
1980*	1,167	41.5	2.7

Source: U.S. Office of Education.

The following table further identifies the funding sources for undergraduate education through student subsidy.

Table 5

FEDERAL AGENCIES--UNDERGRADUATE STUDENT SUPPORT 1971 (MILLIONS OF DOLLARS)

Agency	1971
Health, Education, Welfare	
Office of Education	721
Social Security Administration	455
Health Agencies	39
Veterans Administration	1,068
Defense	85
National Science Foundation	4
Justice and Other	17
	2,389

Source: Federal Budget.

Similar information showing federal support of graduate students for 1972 is shown in the table below.

Table 6

FEDERAL AGENCIES--GRADUATE STUDENT SUPPORT
1972 (MILLIONS OF DOLLARS)

Agency	1972
Health, Education, Welfare	
National Institute of Health	207
Office of Education	49
Other	70
Veterans Administration	190
National Science Foundation	30
National Aeronautics and Space Administration, Justice, Others	15
	561

Source: Federal Budget.

In 1970, higher education costs represented 2.48% of the GNP. Indicators, such as voter refusal to support community college bond issues, show that the public is not willing to support higher education at increased levels. The Carnegie Commission report, "A More Effective Use of Resources," states that the public will continue their support of higher education only if the support level can be maintained close to the present level. If the trend of the 1955 to 1970 period were extrapolated to 1980, the figure would represent approximately 3.3% of the GNP. If we accept the Carnegie Commission constraint, then the total cost for higher education must be reduced 20% by 1980 to 41.5 billion dollars as opposed to the 51 billion dollars (1970 dollars) indicated by continuation of present trends.

Another area of concern in discussing the cost of higher education is the cost trend as compared to the national economy. In the 1930-1960 period, the increase in costs of higher education (based on student credit hour) has been the general rate of inflation plus 2.5%. This 2.5% is the increase necessary due to lack of productivity increase in higher education [32]. This is important in periods of tight financing, dictating either that increased productivity is necessary or that reductions in peripheral costs must be accomplished.

Costs and finance data must be correlated with the market and production, in this case, students and graduates. Most authorities agree that the number of students available for entry into higher education will reach a steady state by 1980. There is a definite possibility, suggested by a reduction in the 1970-1974 period of the number of high school graduates entering higher education, that present forecasts of student numbers in the late 1970's and early 1980's may be optimistic.

c. Program Costs

A continuing problem for engineering education is its higher cost when compared to liberal arts, teacher education, etc. The higher cost is largely attributable to associated engineering laboratories. The laboratories in most engineering disciplines require larger pieces of more expensive equipment requiring proportionally more space than freshmen-sophomore chemistry or physics labs. The same laboratories would also dictate a lower student to faculty ratio as well as requiring more technicians for maintenance of the equipment. This difference in program cost is illustrated by funding formulas for the University of Texas.

Table 7

FUNDING FORMULA FOR FACULTY SALARIES: RATES PER SEMESTER CREDIT HOUR (DOLLARS)

Program	Undergraduate	Masters	Doctorate
Liberal Arts	16.34	43.89	160.73
Fine Arts	31.61	70.32	233.05
Teacher Education	15.27	36.43	137.77
Engineering	28.72	79.37	231.44

Table 8

FUNDING FORMULA FOR DEPARTMENTAL OPERATING EXPENSE: RATES PER SEMESTER CREDIT HOUR (DOLLARS)

Program	Undergraduate	Masters	Doctorate
Liberal Arts	0.96	6.39	30.10
Fine Arts	7.23	24.08	108.36
Teacher Education	3.02	6.02	24.08
Engineering	10.84	24.08	108.36

Source: Coordinating Board--Texas College and University System Policy Paper 9, Feb 6, 1970.

One implication of the cost differential is the natural tendency to cut high cost programs, especially if enrollments are depressed. A workable method of reducing the cost of engineering education to a figure comparable to other disciplines would benefit engineering schools.

Federal support is expected to continue in the future at the same or increased level; however, the funds may come to the universities through different programs such as increased aid for minorities, aid for students from low income families, etc.

Several sources, such as the Carnegie Commission report, "Higher Education, Who Pays? Who Benefits? Who Should Pay?" recommend that tuition be increased until the income from this source equals 50% of the total costs of operating the universities. This would be accomplished by varying tuitions in accordance with the parent's ability to pay, thus shifting a greater share of the total cost directly to middle class parents in addition to their higher proportional support through taxes. There is pressure in some circles to provide student support directly to the student rather than through institutions. Freedom of choice would thus be encouraged, but management problems would be significant because future planning would be difficult.

d. Rising Costs

Five components of costs can be used to review the rising costs of education as follows:

(1) Effects of inflation

(2) Rising faculty salaries

(3) Rising cost of student aid

(4) Campus disturbances, theft, and destruction of property

(5) Growth in responsibilities and activities

A report [33] reviews the cost increases over a year for a number of universities considered to be in financial trouble and indicates an average increase per student per year between 1959-1960 and 1969-1970 of 10.3% with the following approximate distribution with respect to the five components listed above.

(1) 25% due to inflation

(2) 20%+ due to salary increases--faculty salaries generally are 33% of budget

(3) 25% due to increased student aid

(4) 30%- due to campus disturbance

In general, those universities not considered to be in financial trouble allocate less money for student aid, instruction, and research, and more for program and institutional support. In the late 1960's, freedom from adverse income and expenditure effects of serious campus disturbances was also a condition common to all institutions not in financial trouble. This report also recommended allocating funds in large systems on a lump sum basis, rather than specific line items, to avoid inefficiency as a result of system-wide formula allocation of funds. Breakdowns of costs for public and private institutions should also be studied.

e. Cost Trends

Figure 10 illustrates trends in expenditures in both public and private institutions. Public institution expenditures for student education have increased by a factor of more than 5 from 1960-1961 to 1970-1971. Expenditures for this same item in private institutions has increased by only about three times in the same time frame. Total expenditures for student education in public institutions have increased from 130% of the same expenditures at private institutions in 1960-1961 to more than 200% in 1970-1971. Expenditures for auxiliary enterprises in public institution expenditures have increased four-fold in the 1960-1961 to 1970-1971 period, while expenditures for the same purpose in private institutions almost tripled.

Finally, to put education costs in a better perspective, estimated 1973-1974 cost for two states, Indiana and California, are presented as follows: In Indiana, the total budget is approximately 4.5 billion dollars, including federal funds to various programs in the state. The cost of higher education expenditures from the state budget represents 0.5 billion dollars or 11.3 percent of the total budget. In California, the total budget is approximately 15.1 billion dollars, including federal funds, and the higher education costs are 1.8 billion dollars, or approximately 12 percent of the total.

f. Loans and Miscellaneous Funding Sources

At Sloan study institutions,* in 1972-1973 it was estimated that over 40% of the students worked at some campus job. The estimated average yearly income from this source was $400.

The Sloan study shows trends toward more student borrowing to meet educational costs now than in 1952. Approximately 6% of the 1952 classes borrowed and only 4% incurred debts of $2500 or more. The 1970 class showed 32% borrowing to meet educational costs with over one-third of these incurring debts of over $2500. Eight percent of the class reported debts of over $5000.

Several alternatives are presently available to students in most universities, such as short-term loans to meet temporary needs

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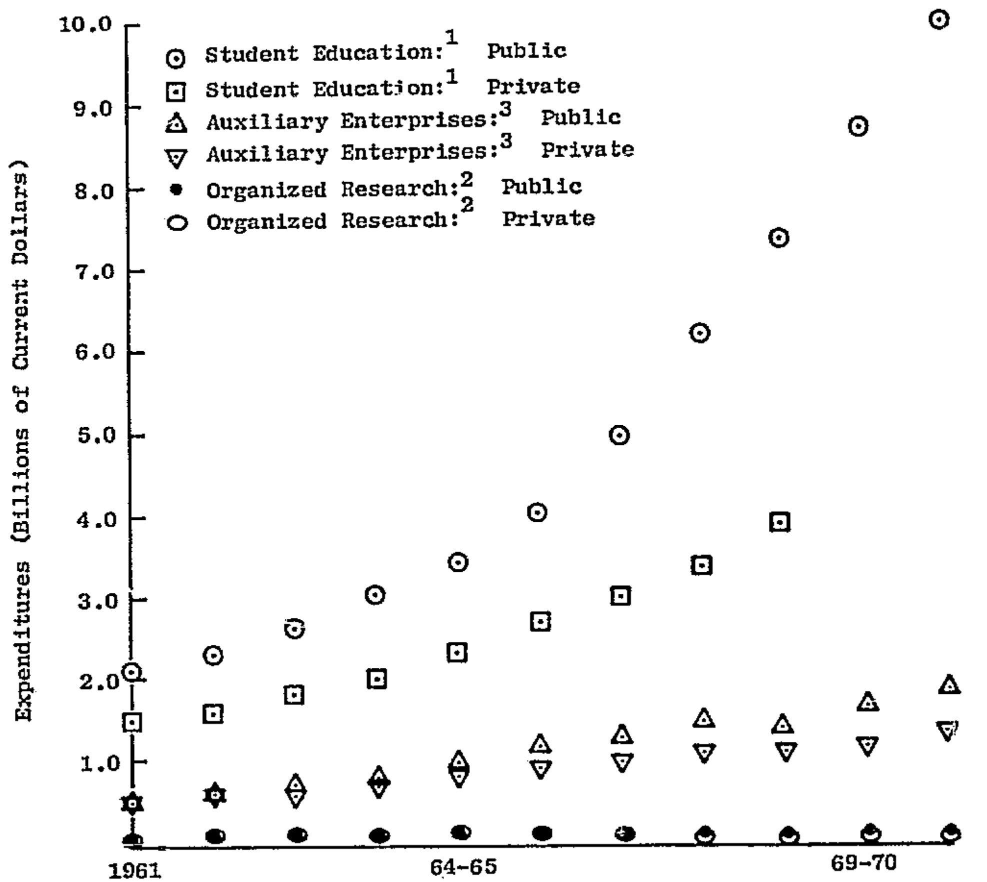
*Amherst, Brown, Dartmouth, Harvard, MIT, Mt. Holyoke, Princeton, Wellesley, Weslayan.



1. Includes general administration, instruction and departmental research, extension and public services, libraries, operation and maintenance of the physical plant, and sponsored activities such as training institutes and related sponsored activities which were specifically financed by outside sources.

2. Includes all sponsored research and other separately budgeted research through 1967-68. Beginning in 1968-69, expenditures of federally funded research and development centers are included with major public service programs.

3. Auxiliary enterprises include student dormitories, dining halls, cafeterias, student unions, bookstores, faculty housing, athletic programs not part of the instructional program, lectures, concerts, and also include expenditures for plant assets from current funds which are not itemized under educational and general expenditures.

Figure 10. SELECTED EXPENDITURE INSTITUTIONS OF HIGHER EDUCATION: UNITED STATES.

and the Guaranteed Student Loan Program (U.S. Office of Education). Some private institutions feel a specially designed program would be more beneficial. The Tuition Postponement Option of Yale University is an example. Unique provisions of the Yale plan are as follows:

(1) A long repayment period of up to thirty-five years, with low annual payments.

(2) An income-contingent repayment feature to protect the low income borrower.

(3) A mutualization feature to redistribute total repayment of the debtor group from low income to high income borrowers.

There are also tax advantages to be enjoyed by participants in the program.

The Guaranteed Student Loan Program, hereinafter called GSLP, was created in 1965 (Title IV-B of the Higher Education Act). Through June 1973, there had been over 6 million loans from 20,000 lending agencies totaling over $5.8 billion involving 3.5 million students. Under the provisions of the Federal Insured Student Loan Program, the federal program under GSLP, the main features are as follows:

(1) A student may borrow up to $2,500 in an academic year.

(2) Maximum outstanding insured loans to a student will be $7,500 for undergraduate training or $10,000 total for all training.

(3) Repayment begins 9 to 12 months after graduation or point where student ceases to carry a half-time academic load.

(4) Repayment may be deferred for up to 3 years while on active duty in Armed Forces, or Action.

(5) Minimum annual repayment is $360.

(6) Repayment maximum period is 10 years.

(7) Interest rate is 7% per annum.

There are also additional attractive interest and insurance factors.

g. White Market

Any discussion of engineering education would be incomplete without including the vast realm of education that is continually underway in state agencies, private industry, and, in fact, any organization or unit with engineering employees. IBM, Lockheed, NASA, all provide the opportunity for closed circuit television classes originating on the Stanford campus. Most state agencies, such as the California Department of Transportation, arrange for employees to attend classes conducted both internally and externally by in-house instructors and/or visiting experts to facilitate maintaining the appropriate level of employee expertise in their respective areas of endeavor. Federal agencies are no different, pursuing basically the same routine.

An additional area that is sometimes labeled differently is training programs for new engineering graduates at many levels of government and in private industry. Although the time spent is usually less, consulting and contracting firms also engage in training programs. Usually, their operation resembles a short apprenticeship, consisting of assigning new employees to work with an experienced engineer for some short period of time to learn the peculiarities of the job.

The respective budgets and expenditure ledgers of the above-named organizations seldom reflect all the expenses involved in this educational process as direct education cost but are charged to several different budgets. Individual expenditure items must be examined to show all monies involved. A typical training session requires not only tuition, books, etc., but in most cases, especially in large organizations, released time from the regular work routine to attend class, funds for travel, and in many cases, even overnight expenses.

5. Professional Opportunities for Graduates

Engineering employment patterns have exhibited fluctuations similar to the overall labor picture; however, there have been some dramatic fluctuations in areas directly influenced by government contracts and research and development expenditures. During the 1970-1971 unemployment crisis, the unemployment rate for engineers rose to 2.9% from 0.7% in 1968. This rate was still well below the 5.9% for the civilian labor force as a whole. The concentration of the over 30,000 unemployed aerospace engineers primarily in Seattle, Los Angeles, and Wichita, Kansas, drew considerable attention. The 1970-1971 unemployment statistics indicate 32% of the unemployed engineers were electrical and aeronautical engineers.

As reported in the Carnegie Commission report, "College Graduates and Jobs," enrollment in engineering programs is extremely sensitive to the trend in engineering employment picture. The cycle has repeated itself several times in the past few decades. If this trend is continued (there is already an indication of increased engineering enrollments), we can expect a peak in graduates 4 to 10 years hence.

In 1970, there were approximately 1,200,000 employed engineers in the United States with 20,000 women included in this figure. The table below outlines the major areas of employment for male engineers in 1960 and 1970.

Table 9

NUMBERS AND PERCENTAGE DISTRIBUTION OF ENGINEERS: 1960 AND 1970 (MALES ONLY)

Sector	1960	%	1970	%
TOTAL	852,016		1,187,932	
Agriculture, forestry, and fisheries	1,394	0.16	3,402	0.29
Mining	14,440	1.7	18,744	1.6
Construction	91,653	10.8	94,813	8.0
Manufacturing	469,224	55.2	642,800	54.1
durable goods	395,290	46.4	539,760	45.4
nondurable goods	73,934	8.7	103,040	8.7
Transportation, communications, and other public utilities	73,251	8.6	104,815	8.8
Trade	27,430	3.2	45,931	3.9
FIRE*	7,582	0.9	10,029	0.85
Business and repair service	24,600	2.9	39,997	3.6
Personal services	608	0.07	1,469	0.12
Entertainment and recreational services	623	0.07	1,285	0.11
Professional and related services	70,526	8.3	121,924	10.3
Public administration	68,769	8.1	102,723	8.6
		[138,140]		

*Finance, insurance, and real estate.

The table shows that in 1970 over one-half, more than 600,000 engineers are employed in manufacturing industries.

The Occupational Outlook Handbook indicates that federal, state, and local governments in 1970 employed over 150,000 engineers, educational institutions 40,000; the remaining approximately 300,000 engineers were employed primarily in the construction, public utility, engineering and architectural services, and business and management consulting services industries. Two-thirds of the engineers were employed in 10 states, with one-third of these in California, New York, and Pennsylvania.

As shown above, the percentage of college freshmen choosing engineering declined steadily from 1966 to 1970 with an accelerated rate of decline between 1970 and 1971. In 1970, approximately 44,800 bachelor's degrees were awarded in engineering. The Bureau of Labor Statistics estimates that approximately 45,000 engineering graduates annually will be needed through the 1970's; however, the number of bachelor's degrees awarded in engineering will be approximately 29,000 in 1976.

Another forecast of future demand for engineers by the Department of Labor estimates a total employment of 1,500,000 in 1985. This represents a 2.7% annual rate of growth, compared to an average 3.7% per year from 1960 to 1968. This would indicate that approximately 44,800 new graduates per year will be required. One should note that one estimate indicates that 38% of the engineering positions in 1972 were filled with nonengineers.

Although the outlook for employment of engineers through 1985 shows more jobs than engineering graduates, several important factors should be remembered as follows:

(1) A significant increase in engineering enrollment could quickly reverse the trend.

(2) Engineering Technology and Industrial Technology graduates can fill many of the engineering positions.

(3) Many graduates in science, mathematics, statistics, etc. can also fill many of the positions classified as engineering.

The production sector of the economy is expected to require a smaller proportion of the labor force in years to come. Consequently, a greater portion of all workers and most of the additional 50 million workers will enter the service sector.

It also appears likely that changing national goals and values will further accelerate this pattern of change. Defense and space expenditures will probably continue their relative decline while expenditures for health care, education, housing, etc. will grow. If this should happen, the effect on the engineering profession will be profound. Some measure of this effect can be seen by examining the record of engineering employment in different industries. The high technology industries, represented by defense and space, employ many more engineers per dollar of business than the service industries.

If national goals continue to be directed away from defense and space, if the populace continues to be concerned about its environment, if high technology is in truth highly energy-intensive, then some of the engineering specialties which have been so influential in shaping curricula for the past decade will be shelved.

The relative employment in the three major areas of the economy from 1890 to 1970, with a projection to 1980, is shown in Figure 11. The trend from production type employment to service type is clearly evident.

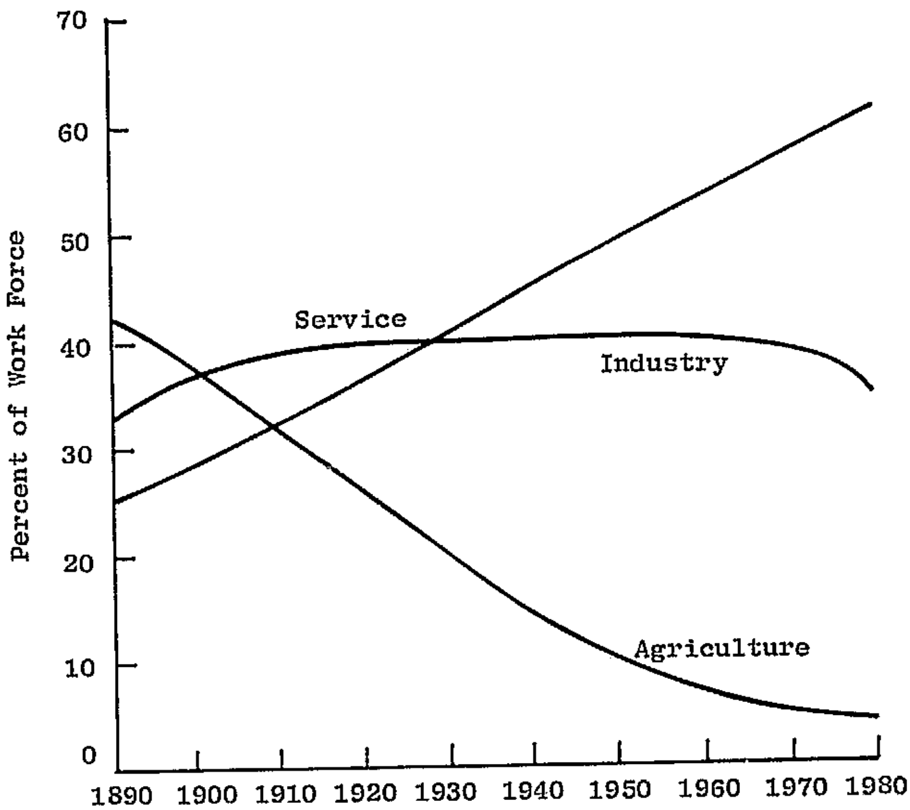


Figure 11 . RELATIVE EMPLOYMENT IN THREE AREAS OF THE ECONOMY.

B. Outside Schools of Engineering

1. Students

In this section of the report, we present a multidimensional profile of the student who is outside the age 18-22 academic program of colleges or universities. This student is typically working full-time and is called an engineer. He may or may not have a college degree. If he has a college degree, it may or may not be in an engineering discipline. While he is called an engineer at his place of employment, he may be a student in a technical area, in a business area, or in a personal development area. This student population that we are going to describe is most diverse.

a. Number of Engineers

Department of Labor Statistics for 1972 indicates that there are about 1,066,000 engineers in the United States.

For comparison, the fall 1973 enrollment data from Engineers Joint Council show 221,197 full-time students and 41,806 part-time students. If we assume that the part-time students are about one-third of a full-time equivalent, then there are about 235,000 full-time equivalent engineering students in academic programs. Hence, we can say that there are about 4.5 times as many persons working as engineers as there are engineering students in academic programs.

b. Discipline Distribution

The Occupational Outlook Handbook lists an estimate for the number of each of several different types of engineers as of about 1970. These numbers are shown below in Table 10. The percentages show clearly the dominance of the older, more traditional branches of engineering. Civil, electrical, industrial, and mechanical engineers comprise nearly 84% of all engineers.

c. Occupation and Education Distribution

Educational Attainment	No. of Engineers	% of Total
Less than bachelor's	476,466	38.3
Bachelor's degree	570,598	45.9
Graduate degree	195,456	15.7

The Occupational Outlook Handbook indicates that about 325,000 engineers (about 30% of all engineers) are registered as professional engineers in one or more states.

Table 10

ESTIMATED NUMBERS AND PERCENTAGES OF VARIOUS ENGINEERING SPECIALTIES (DATA FROM OCCUPATIONAL OUTLOOK HANDBOOK)

Discipline Specialty of Engineering	Estimated Number 1970 (in thousands)	Percent of Total
Aeronautical	60	6.6
Agricultural	13	1.4
Biomedical	3	0.3
Ceramic	10	1.1
Chemical	50	5.5
Civil	185	20.2
Electrical	235	25.7
Industrial	125	13.7
Mechanical	220	24.1
Metallurgical	8	0.9
Mining	5	0.5
TOTALS	914	100.0

Below we show data for both scientists and engineers over the time period from 1950 to 1970 [37].

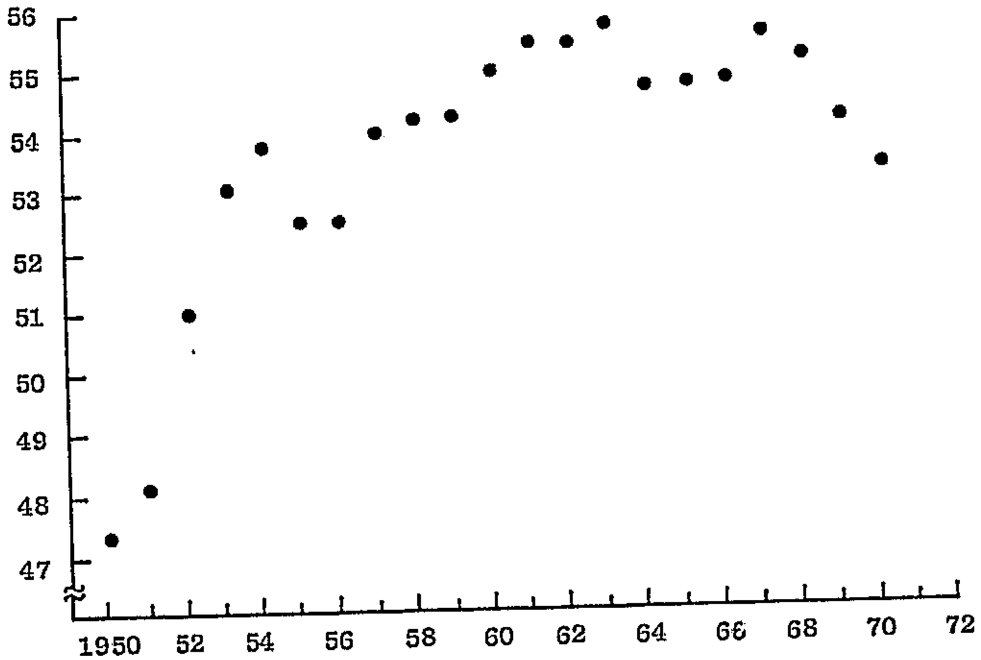


Figure 12. PERCENTAGE OF U.S. SCIENTISTS AND ENGINEERS IN MANUFACTURING.

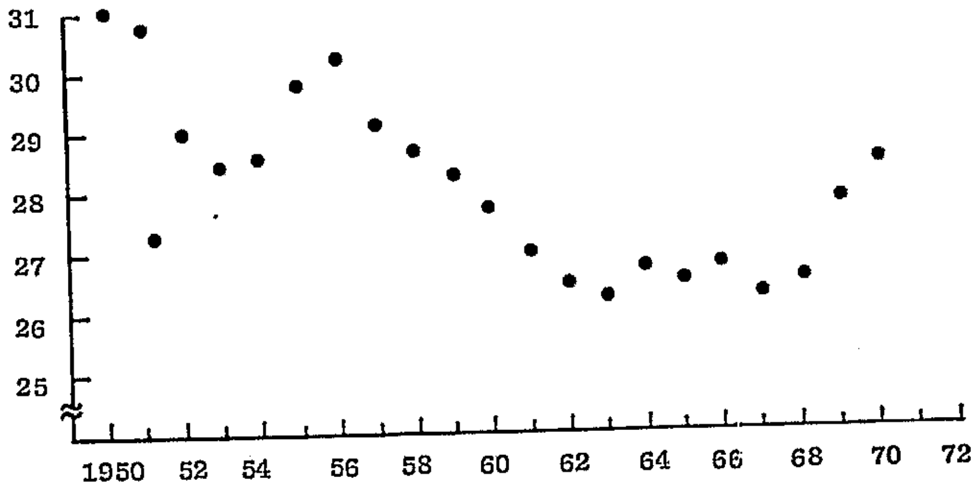


Figure 13. PERCENTAGE OF U.S. SCIENTISTS AND ENGINEERS IN NONMANUFACTURING.

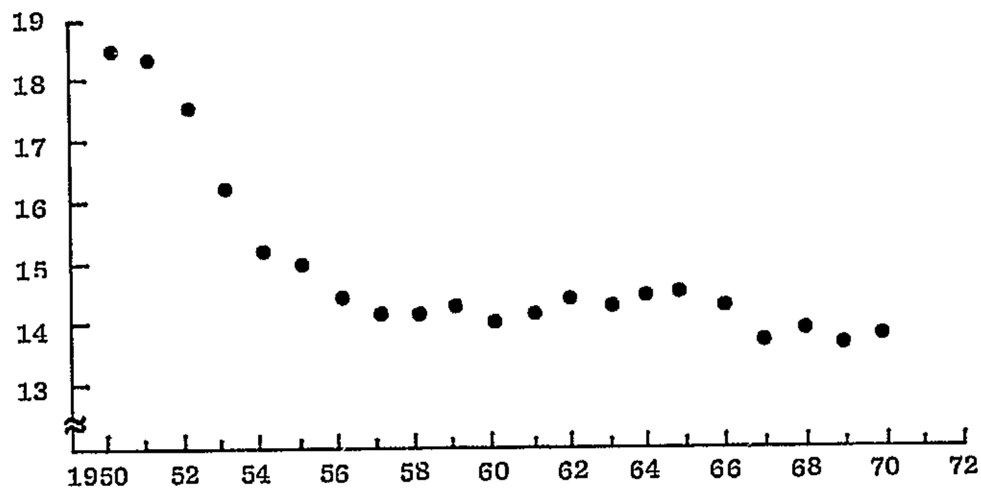


Figure 14. PERCENTAGE OF SCIENTISTS AND ENGINEERS IN GOVERNMENT.

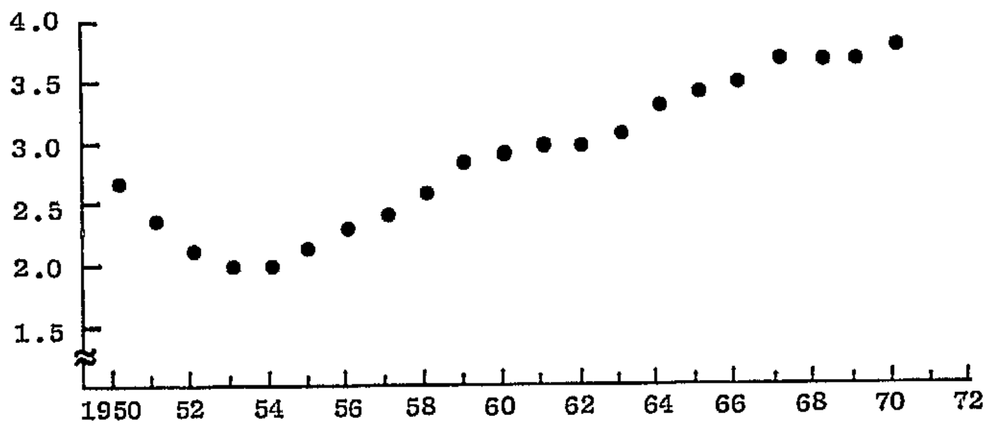


Figure 15. PERCENTAGE OF SCIENTISTS AND ENGINEERS IN COLLEGES AND UNIVERSITIES.

d. Ethnic and Sex Distribution

As Table 11 below clearly shows, engineering in the U.S. is a white man's profession (95.4% of all engineers).

Table 11

DISTRIBUTION OF U.S. ENGINEERS BY ETHNIC GROUP AND SEX

Ethnic Group	Men	Women	Percent of U.S. Population	Percent in Engineering
White	1,199,811	19,697	---	---
Black	14,198	757	11.1	1.19
Spanish origin*	17,237	298	4.4	1.40
American Indian	1,103	63	0.39	0.09
Japanese origin	6,494	132	0.29	0.53
Chinese origin	9,038	82	0.21	0.73
Fillipino	2,142	35	0.17	0.17
Total men†	1,236,160			
Total women†		20,775	51.3	1.65

*As "Spanish origin" does not specify race, all persons included here are also included in the race categories.

†Totals include other races not shown separately.

Source: L. P. Grayson, Spectrum, May 1974, p. 54.

e. Salary Distribution

1970 census data as reported in the Statistical Abstract of the United States 1973 show an average annual salary of $13,447 for 1,210,000 engineers. Table 12 below presents 1970 salary data by discipline specialty with the calculated percentage deviation from the average salary for all engineers.

In order to show the salary status of engineering relative to other selected science oriented salaries, Table 13 is presented below. The Science salary data are from the Statistical Abstract of the United States 1972, p. 529.

f. Age Distribution

Figure 16 shows the percentage of the professional labor force by age for engineers, life scientists, physical scientists, and

Table 12

1970 AVERAGE SALARY DATA FOR SOME ENGINEERING DISCIPLINES

Discipline Specialty	Number in Discipline	1970 Average Annual Salary	% Deviation from Average Salary
All Engineering	1,210,000	$13,447	---
Aeronautical	68,000	14,766	+ 9.8
Civil	173,000	12,675	- 5.7
Electrical	281,000	13,361	- 0.6
Mechanical	180,000	13,436	- 0.1
Other	509,000	10,899	-18.9

Table 13

COMPARISON OF AVERAGE SALARIES OF SELECTED SCIENCE FIELDS TO ENGINEERING

Field	1970 Average Salary	% Deviation from 1970 Average Engineering Salary
Agricultural Sciences	$12,800	- 4.8
Anthropology	14,700	+ 9.3
Biological Sciences	15,000	+11.5
Chemistry	15,300	+13.8
Computer Sciences	16,500	+22.7
Earth and Marine Sciences	14,900	+10.8
Economics	16,300	+21.2
Linguistics	12,500	- 7.0
Mathematics	14,300	+ 6.3
Atmosphere and Space Sciences	15,200	+13.0
Physics	15,900	+18.2
Political Sciences	13,100	- 2.6
Psychology	15,000	+11.5
Sociology	13,000	- 3.3
Statistics	16,900	+25.7
ENGINEERING	13,447	---

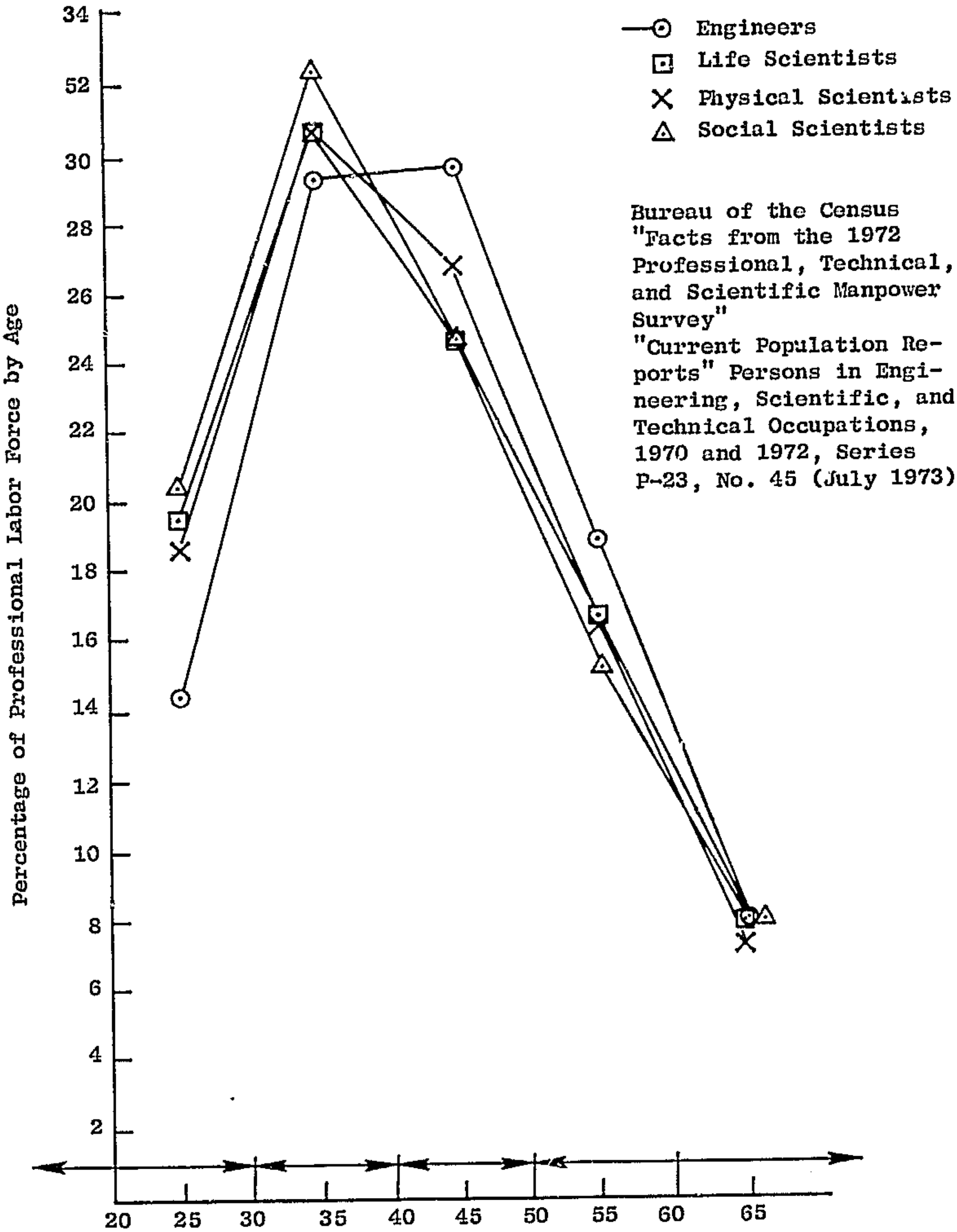


Fig. 16. AGE DISTRIBUTION OF ENGINEERS, LIFE SCIENTISTS, PHYSICAL SCIENTISTS, AND SOCIAL SCIENTISTS (1970 DATA).

social scientists. It is clear from the curves that engineers are the oldest and social scientists are the youngest of these four professional populations. From these data, an average age of 43 for the engineers and 41 for the social scientists can be computed.

g. Geographical Distribution

The number of engineers by state are presented in Figure 17. Figure 17 is self-explanatory. The top ten states have 63% of all the U.S. engineers and the top twenty states have 82% of all U.S. engineers.

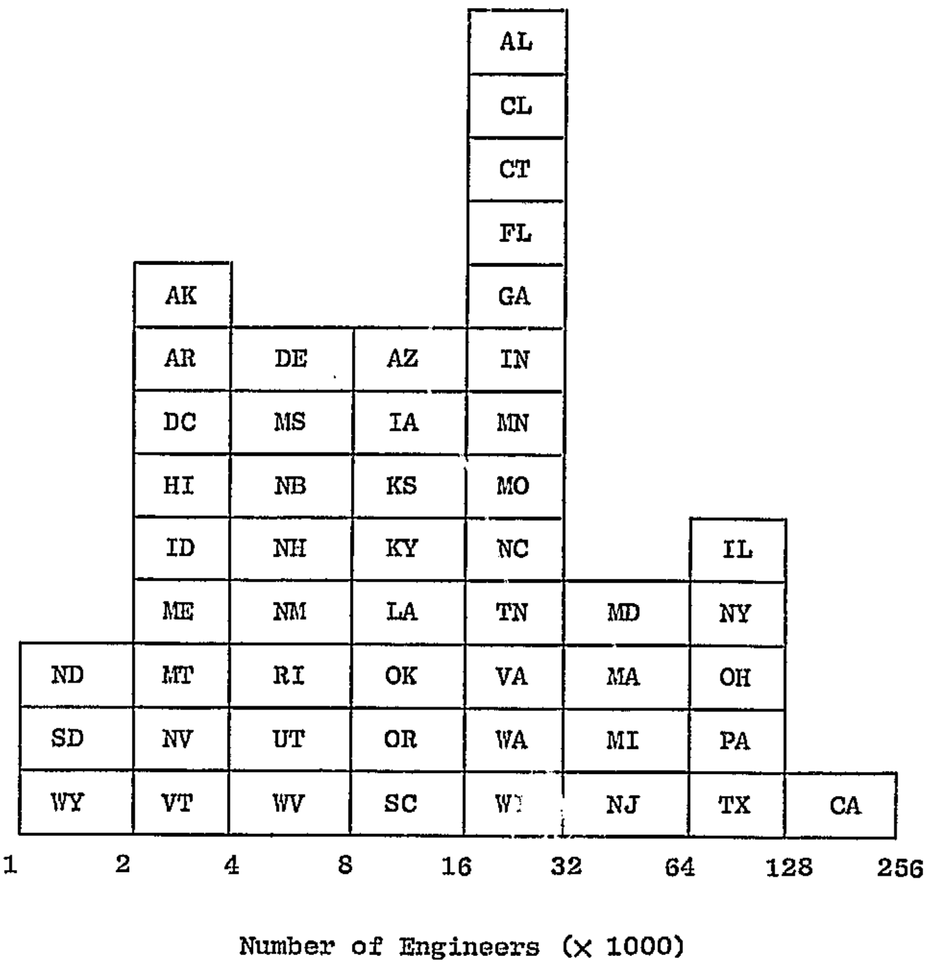


Figure 17. DISTRIBUTION OF EMPLOYED ENGINEERS BY STATE.

The number of engineers per 1000 population are given in Figure 18. The range is 10.23 engineers/1000 population for Connecticut to 1.65 engineers/1000 population for South Dakota. Finally, we show the distribution of states according to the number of engineers employed

			AK	AL					
		DC	FL	MN					
		ID	GE	MO					
		IA	HI	NY					
		LA	IN	PA	AZ				
		NB	KA	RI	IL				
	KY	NC	NV	TX	MI				
AR	ME	OR	OK	UT	NM		MA	CA	
ND	MS	SC	TN	VE	OH	CL	NJ	DE	
SD	MT	WV	WY	WI	VA	NH	WA	MD	CN
1	2	3	4	5	6	7	8	9	10

Figure 18. ENGINEERS PER 1000 POPULATION (BY STATE).

in the state, divided by the number of undergraduate engineering students in the state in Figure 19. States like Maryland, California, Connecticut, and New Jersey import engineers and states like North Dakota, Utah, and South Dakota export engineers.

2. Instruction, Programs, and Curricula

a. Introduction

In addition to schools and industry, many organizations meet the educational needs of engineers interested in continued learning throughout their life. The most important are the engineering professional societies whose purposes are to promote the profession and look after the interests of the engineers that they represent. A range of correspondence schools and private educational institutions and publishers offer instruction in everything from physical skills to intellectual knowledge or personal experiences.

b. Professional Societies

Currently, the primary educational role of the professional societies is through their publication program and their sponsorship of technical conferences and meetings. Both the technical literature and the meetings provide an arena where engineers from various

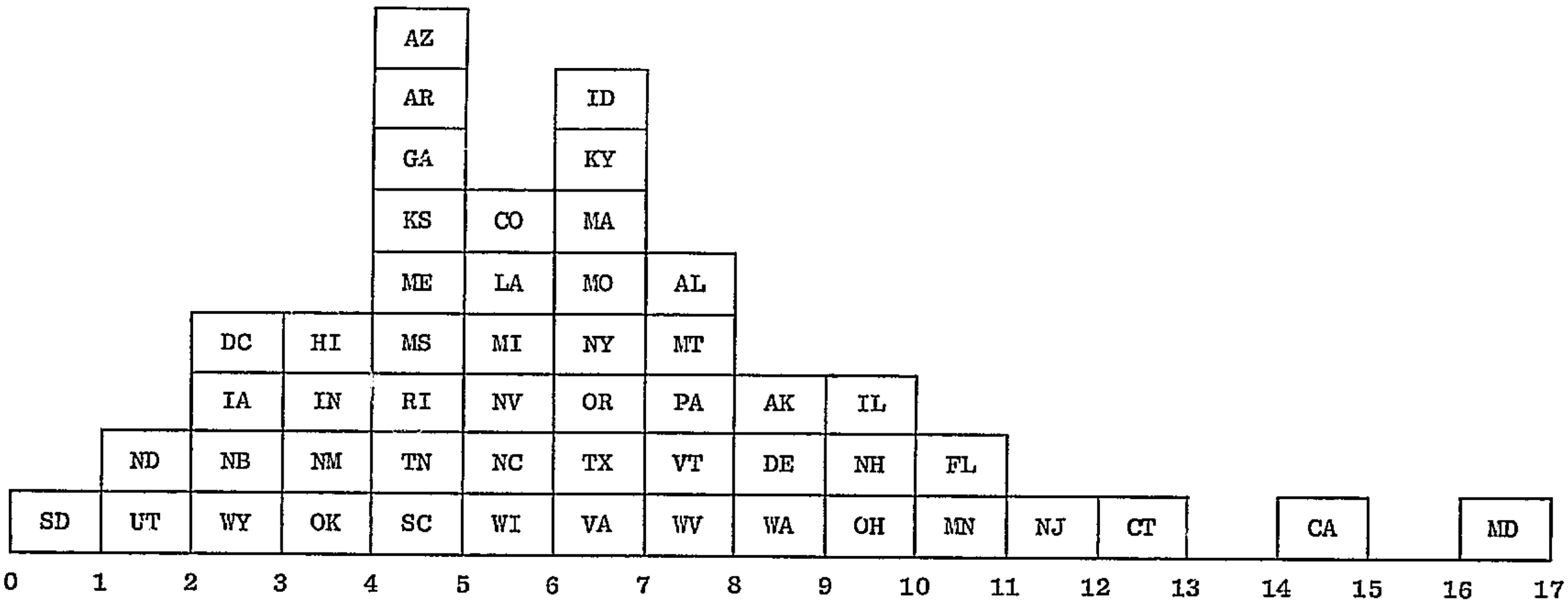


Figure 19. DISTRIBUTION OF RATIO: $\frac{\text{NUMBER ENGINEERS EMPLOYED}}{\text{NUMBER UNDERGRADUATES}}$ BY STATE.

industries and universities can come together and share technical knowledge. These activities tend to be discipline oriented and have three educational purposes: (1) conveying an awareness of new technical directions, (2) teaching the fundamentals of thought in a specific field, and (3) covering the engineering state of the art in a current technology. The formal technical papers represent what appears in print in announcements and journals. But the informal activities at conferences and meetings are perhaps a more important educational activity than the formal papers. Consulting with colleagues, asking questions, informal conversations, and meeting individuals, are all crucial ingredients of learning at technical conferences.

The engineering professional societies are now moving into more formalized instruction which was formerly the exclusive domain of universities and publishing houses and industry. Professional societies are now organizing and publishing books and sponsoring short courses, lecture series, and workshops. These courses are self-supporting financially, and the authors and lecturers are hired from industry and universities. The professional society usually does not try to compete directly with courses offered by universities except where costs are excessive or the university uses an inconvenient delivery system. The professional society exists to serve the needs of its members, and when its members lack educational materials in a new subject area, the society will take the initiative to produce them.

The largest engineering professional society, the IEEE, now offers 8 to 10 short courses per year and plans to be offering 80 per year within 10 years. They now offer 3 self-study courses and plan to increase them to 83 within the same 10-year period. Thus, a very rapid increase in the involvement of professional societies in formalized education is expected. Many delivery systems: books, lectures, video-tapes, audio-tapes, self-study correspondence courses (some with graded assignments and tests and some without student-instructor interaction), are being used now.

c. Publishing Industry

Engineers who want an organized subject treatment in an existing field buy a textbook or reference book from a publisher. For recent knowledge that has not been published in book form, an engineer will turn to an article in a trade journal or "throw away" journal. These magazines are supported by advertisers but also serve to provide an important educational medium for informing engineers on the design and application of the latest ideas and devices in a field.

d. Correspondence Schools

A number of independent correspondence schools exist across the country which offer many courses of interest to graduate engineers, such as business, finance, engineering refresher and engineering technology courses. Two of the largest are the International

Correspondence Schools in Scranton, Pennsylvania and the La Salle Extension University in Chicago, both of which offer an extensive selection of courses. The Alexander Hamilton Institute teaches the financial workings of a business. Book publishers, such as the McGraw-Hill Book Co., CREI Home Study Division, offer correspondence courses. The Grantham School of Engineering in Hollywood, California, offers an Electronics Engineering Technology Degree by correspondence, except for four months required in residence to complete the laboratory portion of the curriculum.

e. Philanthropic Foundations

The large philanthropic foundations are heavily involved in education at all levels from preschool to graduate programs, but they do not have any significant involvement in continuing education or any post-degree educational programs.

f. Personal Development Organizations

A person who wishes to learn and grow in nonintellectual areas can enroll in courses focussing on individual development. These range from the popular and long-established Dale Carnegie Course to more recent personal growth and experiential seminars such as those offered by Esalen, National Training Labs, Center for the Study of Persons, EST, and many others. These latter groups attempt to enable individuals to reach a more dynamic level of living, both in relationship with self and with others.

g. Course Offerings

Current programs for continuing engineering, their history, and other details, are described in Appendix 2.

3. Costs and Finance

a. General

A noteworthy trend in continuing education is that many companies provide them to employees at company expense and on company time. This trend is most evident among large high-technology corporations. Many industries provide tuition reimbursement for job-related courses. In some cases, job-relatedness is stretched to include broadly ranged topics; the underlying justification for the extension of job-relatedness is that, by integrating personal and professional growth, unity of technical vitality is achieved.

Cost information is difficult to obtain. Rarely is there a direct answer to the question of how much money is spent annually for education. Companies also differ in their need for continuing technical education. Some companies have virtually no need, while others participate in a large variety of programs, to ensure that their employees can stay current.

The available numbers for cost of continuing education show a range of expenditures. For example, Kodak spent about $1.3 million in 1973 on its tuition reimbursement program for 3,260 employees, or about $400 per employee. General Electric's Research and Development Center has spent about $35,000 annually on about 90 employees, also about $400 per employee. The City of Palo Alto will pay up to $400 or $500 per year per employee for job-related professional development that can include tuition, books, journal subscriptions, or conference fees. Siltec spends roughly $10,000 per year for education for 14 engineers and roughly 450 production people. General Electric's Nuclear Energy Division spends roughly $600,000 annually on education for their staff of about 4,500, including 2,500 professionals, mostly technical. Tuition reimbursement is a small part of this, about $62,000 for 1973. Bechtel spent $600,000 in 1973 for educational development for their staff of about 4,600 technical people, including 3,500 engineers.

That these figures are about what might be expected, can be justified by a sample calculation. We will assume, based on calculations of the half life of a curriculum contained in Ref. 34, that engineers should count on replacing or updating their knowledge through formal course work every ten years. Presumably, the practice of engineering keeps engineers reasonably up-to-date in their specialties. Replacing an engineer's college education of 120 semester hours every ten years amounts to taking 12 semester hours or about 4 courses a year. We will assume that an engineer can purchase courses at about $100 per credit hour or take short courses at about $100 per day. We will also assume that a three-day short course is about the equivalent in formal instruction of a three-credit course, although admittedly less demanding in work by the student. By this estimate, each engineer would buy (or his company would buy) about $1200 of continuing education a year. This estimate can be cut in half for companies that have enough engineers so that they can purchase courses for their company at about $50 per credit hour or per day, a reasonable estimate for the cost of courses that are offered to 10 or more engineers in house. Thus, most companies could purchase continuing education for their engineers at about $600 per year.

Low technology companies need less education for their engineers. Companies that are satisfied to see their engineers taking only one course per year (and thus replacing their college education only once during a working life of 40 years) can purchase courses for them for about $300 per year on an individual basis or about $150 per year for classes.

Multiplying estimates of annual costs ranging from $150 per engineer per year for one course taken in a class to $1200 per engineer per year for four courses taken individually by the one million engineers in the United States gives annual costs of continuing engineering education ranging from $150 million to $1.2 billion.

b. Benefits

Most companies reward job performance more than they do keeping current. Education may even be seen as counter-productive by taking time from the job. Some companies have policies that reward the taking of a degree by giving a special salary review that usually means a salary increase. However, that does not reward the taking of non-credit courses or the taking of credit courses without a degree objective.

One benefit of course attendance may be insuring against technical obsolescence that is so severe that the engineer loses his job. During the 1969 to 1971 aerospace recession, unemployment among engineers was about 3%. If we can take this as a maximum risk for engineers who find themselves trapped in obsolescent specialties, we can calculate the approximate benefit to an engineer of taking extension courses. We will assume that the engineer has a 3% chance of losing his job because of technical obsolescence. He can thus afford to invest 3% of his salary to prevent this risk. Taking a typical engineering salary of about $20,000 for an engineer in mid-career, we can see that he can afford to spend about $600 on continuing education or to take about two to four courses a year even if his company does not reimburse him for tuition. If the company reimburses tuition, his actual expenses may be limited to travel and possibly purchase of books.

c. Design Projects

Industry/school interaction in design projects and systems studies is growing. In such programs, industry presents a real problem, sometimes supplied money, material, and expertise, and students work on the problem with varying degrees of faculty support. Some schools and industries have developed formal programs of interaction along these lines. Stanford's Industrial Affiliate Program and Dartmouth's Partnership Program are examples. The Stanford Engineering Case Study Program is a way to institutionalize interesting engineering case studies so that they can be used repeatedly by engineering students. There are indications that such interactions will continue to increase as both schools and industries realize their benefits.

d. Sabbaticals and Exchanges

Some industrial representatives indicate that faculty would be welcome for sabbatical leaves. Industrial sabbaticals are now small but seem to be growing. The ASEE Internships in Engineering Practice Foundation program enables engineering faculty to spend a year in industry.

In contrast, the path from industry to schools appears to be narrower. The few people who receive sabbatical awards from industry tend to be senior scientists or engineers from large research oriented companies, such as Du Pont, General Electric, Kodak, Weyerhauser, and Xerox.

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Appendix 2

RECURRENT LIFELONG EDUCATION

One of our initial major concerns in considering the future of engineering education was the durability of the educational foundation for the working engineer. Especially in those areas where knowledge and technique are rapidly changing, the technical vitality of the working engineer is usually strongly dependent upon the kind of post-secondary education he has had and his willingness and ability to keep himself current throughout his career. This problem was a major concern of the Holloman Report [1] on engineering education.

We believe that a key to the solution of the problem of continuing technical vitality of engineers is a revision of our concept of the time span of education in the life of the individual. Typically, we think of the initial few years of the life of a person as a play period. This play period used to be the first six years of life, although now it is even seen to be as short as the initial two years. There follows a period of concentrated educational preparation for adulthood and work, perhaps as long as 18 to 20 years. The work span of the individual then encompasses the next 35 or 40 years of his life, followed by a shorter period of retirement from work, perhaps a return to "play."

The education of the person is thought of as the foundation of intellectual and cultural resources upon which he or she relies for the rest of adult life. We question the efficacy of this model of education. A Dane, Werner Rasmussen, has drawn an illuminating parallel between the present role of education in the life of the individual and the supplies for an expedition about to set out across a desert:

> "With more intensive adult education it may be possible to reduce the pressure on the supplies of education to adolescents and young adults. At the present time, there is everywhere a tendency to overload these supplies, because they are considered the baggage for a lifetime. We can compare it with an expedition to a big desert--tropical or arctic--where no supply stations of any kind are established. By the time it sets off on its lengthy journey to the desert the expedition must have large supplies of food and other necessities. The situation would be entirely different if there were stations or depots along the route. The lifelong journey should in the future be supported by supply stations. It will thereby be possible to travel more lightly, which means it will not be necessary to load the memories of young people so much. This will at the same time be of great value to the educational processes during these earlier years. It will be an easier task for the teachers to ensure the motivation and attention of their young students." [2]

Herbert Striner, in quoting Rasmussen, notes further that our present educational system attempts to supply the traveler with a full set of educational provisions for this 40+ year journey, but..."unfortunately most of the provisions with which we equip the individual are of perishable quality. By the time the traveler reaches a third or so of his way, he finds that the food is no longer in condition to provide nourishment to his mind or to his body." [3]

A. Recurrent Education: What Is It?

An alternative educational model, "recurrent education," would allow for formal education to alternate with other social activities during a person's life span. We recognize that much education occurs in other social spheres, i.e., work and leisure, and we believe that a mutually beneficial cross-fertilization and enrichment of the three spheres of activity would result from alternating them over the life span of the individual.

Much of what we conceive of as a system of recurrent education is already occurring. Industry, especially scientifically concerned industry, does encourage and provide technical career-related education for many of its workers, usually on a part-time basis. In addition, there are a plethora of part-time adult education and extension programs through universities, colleges, and junior colleges. These programs are often, but not always, cultural-informational in content, rather than career-oriented. In general, however, the current system of adult education is notoriously lacking in integration and articulation for those whose goal is education along some career path. Additionally, under the present system it is difficult for a person supporting a family to devote any substantial portion of his time to formal education We shall note later several suggestions for providing financial support for some specified period of time for heads of a household.

In many institutions there is a bias against admission of adults as full-time students and even the extension or adult education programs are not quite legitimate: faculty are paid less for teaching in these programs and are often not in the promotion-tenure mainstream. Costs to students are often substantially higher for participation in off-campus or evening programs, and often the campus will not recognize the credits earned as part of a regular degree program.

Finally, the counseling and advising programs for adults is inadequate. We do a poor enough job of advising and counseling students located on campus; we fail miserably in attempting to get such information to adults at large.

B. Some Advantages of Recurrent Education

We have suggested above that one of the concerns which has drawn us to the concept of recurrent education is the need for the continuing technical vitality of professional people. In many areas of fast-changing knowledge, one large dose of education will simply not suffice to keep an engineer current in his discipline. Thus, recurrent education is a necessity for life-long technical vitality for many people in the work force. But there are many additional plusses for a system of recurrent education to which we would call attention.

(a) The second Newman report, in considering cost-effectiveness in education, concluded that "...the greatest gains (in cost-effectiveness) will come from a concentration on effectiveness rather than cost." [4] The report noted that motivation for education varies over the lifetime of an individual and between individuals. It concluded that a recurrent pattern of education provides a better motivational match for most students than the traditional pattern [5].

(b) Changing manpower requirements will require many people in the work force to change their careers significantly. This is especially true in the advanced industrial countries. Recurrent education will facilitate these adult serial career changes.

(c) There are inter- and intra-generational inequalities in education which are now seen as unjust. The younger generation has had and will have much greater educational opportunity than the older generation, but a system of recurrent education could allow those adults who feel relatively deprived a second chance at education. The foregoing holds also for members of the younger generation who now do not elect to continue in higher education. They would not find the opportunity forever foreclosed to them under a system of recurrent education.

(d) There seem to be fundamental social disadvantages to an educational system which keeps young people in an irresponsible social condition until they are 18 to 22 years of age. The world of work probably enhances reality-testing, self-confidence, personal responsibility, and maturity. Although young people reach physiological and intellectual maturity a year earlier than the previous generation, they are kept dependent longer [6]. A system of recurrent education would allow them to "stop-out" to enter the workplace with some assurance that they could continue with their education later without penalty.

(e) Young engineers seem increasingly to be dissatisfied with their careers, in part because of their unrealistic expectations about work [1]. An educational system which encouraged "stop-outs" and welcomes and supports adults would help reduce these discrepancies between expectations and actual work.

C. Recurrent Education in Europe

In many respects, the Western European countries seem to have made a stronger commitment to adult education than we have yet made in the U.S. Striner [3] reports that at the Second Roundtable on Permanent Education in Paris, June 1971, the Council of Europe in their Committee for Out-of-School Education and Cultural Development, dealt with the question of moving toward an educational system which continues to act throughout the individual's life span. Of particular interest is their general introductory statement:

> "Technical developments, society's needs, increasing leisure and growing individual needs call for a determined drive to reshape adult education into a coherent system geared to the demands of our age.
>
> If it is to be fairly shaped, adult education must be seen as a factor making for the transformation of the whole education system with an eye to permanent education. First of all, it is essential for the purposes of permanent education that adults be entitled to adequate time for study, within their normal working hours, and with no loss of pay. This system should be embodied in law or made generally applicable by widespread agreements and specific provisions should be made as to its financing. Permanent education begins with a pre-primary stage designed to offset inequalities resulting from the differing social and cultural family background. At all levels, it presupposes: (1) a sensible system of study units, freely spaced in time, with considerable freedom of choice; (2) a range of studies ensuring an education which, at all levels, is general, cultural, social, and civic; (3) a system of continuous guidance whereby the individual's personal aspirations and society's objective needs may be reconciled; (4) encouragement for creative faculties, spontaneous reactions and critical outlooks, all of which are of immense importance in a highly organized society in which science and technology predominate; (5) the principle of self-education under the active guidance of teachers by means of the widespread use of up-to-date educational and communications techniques and group dynamics." [7]

Striner further reports that many of the European countries are acting in several ways to make these propositions a reality. In the next paragraphs, we describe several recent relevant developments in Britain, France, and West Germany.

1. Britain

One of the more interesting recent experiments in broadening the opportunities for adult education is the Open University in Britain. In the Open University, which began enrolling students throughout Britain in 1971, anyone who is at least 18 years of age and who can read and write is eligible for admission. It offers degrees in arts, educational studies, mathematics, science, social sciences, and technology--all by a combination of written material, televised and taped materials (in cooperation with the BBC), especially produced study guides and tests delivered and returned by mail, 270 regional tutorial and testing centers, and usually a one-week summer residential period for each course of study [8].

These courses are intended to be of quality equal to similar courses offered at other universities in Britain. The quality is guaranteed by a system of external examiners drawn from the leading universities of Britain. Many teachers in U.S. universities and colleges are using Open University materials in their regular courses.

The response to the Open University has been greater than could be accommodated by the facilities and staffing. In its first year, with a limited course offering, the program attracted 41,000 applicants for its quota of 25,000 student places. In 1973, there were over 37,000 students taking about 44,000 courses. About 39% of these students are in the 26-35 age group and 31% are in the 36-45 age group. About 30% of the students are school teachers, 13% are housewives, 12% are in the "professions and the arts," 11% are "technical personnel, and 10% are clerical and office workers.

During the years 1971 to 1973, as enrollment grew from 25,000 to 37,000 students, noncapital expenditures for the Open University grew from 7 million to more than 12 million pounds (or more than $700 per student), 85% of which was provided by the British Government. This represents a major and growing commitment to adult higher education.

2. France

In July 1971, legislation was passed in France which recognized as a "national obligation" the continuing training and education of French workers. The legislation, which reflected a long and difficult negotiation between French management, labor, and the Government, imposes an obligation on each employer of 10 or more employees to provide for worker training or, alternatively, to pay a tax which will rise to 2% of the payroll in 1976. These funds will be used by the Government to encourage or set up employee training programs involving universities as well as other public institutions of learning.

One of the most important elements of the new legislation was a system of compensation for the employee during training. In some cases, the employee will continue to draw his wages from his employer and the employer may be reimbursed in part by the state. In other cases, the employee may be paid directly by the state. At any rate, most French wage earners now have a legal right to a maximum of one year of training for several purposes, e.g., to change occupations should they be threatened with unemployment, for first employment, for refresher or advanced training courses, etc. Most importantly, they and their families will continue to receive an income which will be proportionate to their regular wages.

3. Germany

Of the European countries, West Germany undoubtedly has made the most thoroughgoing commitment to worker training. The Employment Promotion Act of June 25, 1969, "established the right of German workers to take training and education for a new profession or to train for additional skills in their own profession and to be subsidized during the period of training." From the American point of view, it is interesting to note that Germans see this process of the worker continuously upgrading his skills as an appropriate response to their tight employment situation, rather than to a situation of high unemployment.

As Striner sees it, the key problem in adult education and retraining is the support of the adult student and his family. Under the 1969 law..."The average German worker who participates in a training, retraining, or educational situation for as long as two years on a full-time basis, receives not only his education free of charge but also, on the average, approximately 70 percent of his former wage while in training!" During 1971, over a quarter of a million, or about 1% of the West German work force was involved in one of these retraining and education programs.

Funding for these programs comes from equal employer and employee contributions to the unemployment insurance fund. The contribution rate is approximated 2% of earnings and the expenditures for the programs were about 1.9 billion marks in 1972.

This German program probably represents the most ambitious adult education program in Europe. By providing for the financial needs of the worker and his family during an adult educational period, the Germans have taken a major step toward insuring the real possibility of lifelong education for their citizens and enhanced technical vitality for their work force.

D. Recent Developments in the United States

In this section we shall trace the growth of some of the concepts of recurrent education in the United States. The major ideas seem to be striking a resonant chord among many of those currently writing about national educational policy and material manpower policy. Thus, we begin our discussion with the 1971 Carnegie Commission Report, Less Time, More Options, and conclude with the second Newman Report to HEW, National Policy and Higher Education.

1. Less Time, More Options, the Carnegie Commission Report [6]

In this groundbreaking Report the Commission focussed on two ways by which the traditional "front-end load" model of education might be modified. First, it proposed shorter degree or credential programs in both undergraduate and graduate education. These shorter degree programs would be possible if one could later re-enter the education stream to advance another step in his career path. Accordingly, the second major departure from traditional education was the recommendation that education "be available to persons throughout their lifetimes and not just after high school." The Commission recommended that..."young people be given more options (a) in lieu of formal college, (b) to defer college attendance, (c) to step out from college in order to get service and work experience, and (d) to change directions while in college." In order to encourage this freedom to defer college until later, the Commission further recommended

> That all persons, after high school graduation, have two years of postsecondary education placed "in the bank" for them to be withdrawn at any time in their lives when it best suits them.

The Commission proposed a variety of ways of providing this access to education:

> This can be accomplished by (a) providing no- or low-tuition community colleges within commuting distance of nearly all Americans, as we have recommended elsewhere, or (b) by adding to social security a program for "educational security" to be paid through payroll taxes on employers and employees, with the benefits to be available on application after a period of sustained employment, or (c) by making grants, work-study opportunities, and loans available at any time during life, or (d) by providing through employers and unions the opportunity for educational leaves, or (e) by providing educational grants to persons following military and other service activity; or by some combination or combinations of the above programs.

Of particular interest here is the idea of an "educational security program" financed through payroll taxes and which presumably would be applicable at least to all persons covered by the social security system. Such a program would probably vastly increase the number of adult students who could realistically consider continuing their formal education. (We shall discuss below a similar proposal by Striner, which includes cost estimates.)

The Commission explicitly recognized the value of recurrent education for adult students and, importantly, the special contributions to education which might be made by these older students.

> Society would gain if work and study were mixed throughout a lifetime, thus reducing the sense of sharply compartmentalized roles of isolated students v. workers and of youth v. isolated age. The sense of isolation would be reduced if more students were also workers and if more workers could also be students; if the ages mixed on the job and in the classroom in a more normally structured type of community; if all members of the community valued both study and work and had a better chance to understand the flow of life from

youth to age. Society would be more integrated across the lines that now separate students and workers, youth and age.

Thus, the Commission recommended:

That opportunities be created for persons to reenter higher education throughout their active careers in regular daytime classes, nighttime classes, summer courses, and special short-term programs, with degrees and certificates available as appropriate.

Higher education is now prejudiced against older students. They should be welcomed instead. Too often they are looked upon as inferior. Yet older students will help end the in loco parentis atmosphere of many campuses, add maturity to discussions, and make a more balanced community out of the college.

Finally, the Commission recommended:

That alternative avenues by which students can earn degrees or complete a major portion of their work for a degree be expanded to increase accessibility of higher education for those to whom it is now unavailable because of work schedules, geographic location, or responsibilities in the home.

2. Striner's Proposal for a National Economic Security Fund

Striner's proposal resulted from his examination of European adult education policies (which we have summarized above) and is contained in his book, Continuing Education as a National Capital Investment [3]. As the title implies, Striner is concerned with improving the quality of the U.S. work force as well as bringing into the work force those who now seem unemployable because of their lack of needed skills. He cites the record of West Germany in arguing that education and retraining is a more rational way to use unemployment insurance (rather than waiting for people to become unemployed and then briefly supporting them) and can have an important effect in reducing both unemployment and inflation.

Striner argues that if the individual state unemployment insurance funds were federalized, and if a payroll tax of 1.5% were instituted on all wages up to $9000, the funds generated would suffice to cover the regular unemployment security benefits with enough remaining to fund yearly training and stipend costs for 1% of the U.S. work force (800,000 workers). He would enact a permanent education and training law.

> which makes it a right for every worker over the age of 17 to pursue an education-training program. Such a program could be for as long as 24 months, on a full-time basis, with all educational costs and a personal income stipend

provided. The stipend should approximate, on the average, three-fourths of the worker's immediately prior to unemployment income; it should relate to the size of the family or number of dependents, as well as prior employment income, with a reasonable upper limit. For those with no prior work experience, a stipend should be provided to cover basic living needs. This new law should specify that additional funds are to be made available for special things necessary for successful education-training programs and placement; e.g., travel, short-period housing, special tools, etc.

These ideas about the importance of recurrent education and Striner's concrete proposal for funding have now found their way into at least two reports (on work and on higher education) to the U.S. Department of Health, Education, and Welfare. We look briefly at these two reports.

a. Work in America

Work in America, a report of a special task force to the Secretary of HEW [9] examined the relationship between work, education, and job mobility, concluding that there is a strong case on economic, health, and other social grounds for opportunities for mid-career retraining. For example, the report finds that over 40% of blue collar workers over 40 years of age have thought seriously of making an effort to enter a new occupation and would enter an educational program to acquire new skills if such a program were available that promised a reasonable living allowance. The report notes Striner's concept of worker retraining as a "national capital investment" and specifically offers two alternative "worker self-renewal programs."

The first option, a minimal worker self-renewal program, would provide for training and a living allowance for a smaller number of workers who wish to move from declining industries or job categories into growing industries or higher skill categories. This program would be designed to include 500,000 worker per year at an annual cost of $3 to $4 billion. This amount could be financed with a 3/4 percent addition to the payroll tax on income up to $9000. The report argues that the productivity effects of such a program would have a maximum impact on inflation, but a small impact on unemployment.

A second level of program, a "Universal Worker Self-Renewal Program," would be closer in concept to a worker sabbatical. This program, open to all workers, would offer a maximum of six months of sabbatical every 7 years or 1 year every 14 years for either skill upgrading or liberal arts experience. At this level, the program would be about 6 times as expensive as the smaller program and about 3 million workers would be enrolled at any time. The program would have a significant impact on unemployment and would bring social benefits to a much wider segment of the population. The $22 billion annual cost could be captured in part from the $20 to $30 billion which industry already spends on worker training, in part from the $27 billion spent on higher education, and in part from the $7 billion annual expenditure on manpower training.

Both of these worker self-renewal programs follow from the major theme of the report, that work is central to the physical, emotional, and social well-being of our citizens and that work in general needs to be designed taking much more account of these consequences of the workplace. In this process, education plays a major role in enabling the worker to be more than an automation. Accordingly, the report sees adult education as especially important:

> By equating education to a youth activity and by confusing the notions of education and schooling, we have placed too many of our resources in traditional schools designed for people under 21 years of age. We have neglected the fact that education is a lifelong experience, and often occurs outside the classroom. And, as many educators feel, the desire for education often increases with age as does the seriousness with which students approach it. Recognition of these facts would open up several important options for worker training--from making education available to workers at later stages in their lives to encouraging education in places other than the traditional schools.

b. The Second Newman Report: National Policy and Higher Education [10]

The second Newman report sees recurrent education as one of the new requirements for effective education since it provides an opportunity for new careers, matches the needs of most students better than the traditional academic lockstep, and it would allow..."a period of personal reorganization..." later in life. The report acknowledges the many current modes of adult education, but finds many of the problems (integration, articulation, funding, etc.) which we have noted above. Several of the reports' recommendations for reform of post-secondary education deal explicitly with recurrent education. In particular, the report recommends:

> --More conscious and deliberate choices by young people as to whether to go to college, when to go, and what kind of institution or program to attend--aided by the widespread availability of information about the nature of programs and institutions.
>
> --Greater opportunity for individuals to return on a recurrent basis to a full range of educational programs.

The report proposed that the Federal government consider the following recommendations:

> --We believe that greater exposure of students to the productive activities of society outside schooling would help

make college opportunities more valued and increase the ability of students to profit from the classroom experience. Accordingly, we recommend that the Federal government place increasing emphasis on work-study and internship forms of student aid funding, and undertake new efforts to upgrade the jobs in these programs into significant productive experiences. Specifically, we recommend that 20% of work-study funds be allocated on an incentive basis to institutions willing to upgrade the work component into a significant learning experience.

We further recommend new federal legislation, a "G.I. Bill for Community Service," designed to legitimate breaking the educational lockstep for a period of service in selected national, regional, or local community programs. The benefits, like those of the G.I. Bill, would accrue during the period of service and could be used later whenever the volunteer chose to enroll at a post-secondary educational institution. This program would supplement existing federal student assistance, and extend the concept of service, in addition to need and academic ability, as a legitimate basis for the award of federal student aid.

--There is widespread agreement that the encouragement of recurrent patterns of education should become a new national priority. Yet few agree on what strategies should be employed to finance access to post-secondary education on a life-long basis. Many employers have some provision for financing recurrent opportunities for their employees. The Social Security system, pension funds, unemployment compensation, federal student assistance programs, and new concepts such as the creation of an educational trust fund have all been put forward in recent years, each with a different set of training, educational, and "quality of life" purposes in mind, and each affecting different constituencies. Accordingly, we recommend that the Secretary of Health, Education, and Welfare commission a comprehensive analysis of these financing strategies, develop a forum for the public discussion of the competing priorities and diverse interests involved, and develop an effective program of financing of students during recurrent periods of education.

E. Recurrent Education in the Next 20 Years

Even with no special funding or programs, young people are beginning to delay their enrollment in college or, once enrolled, are "stopping out" to gain nonacademic experience. During 1970, one in fifteen Harvard College students were on academic leave. We think this is a healthy trend which should in the long run result in more highly motivated students who are more firmly grounded in the world of work and adulthood. Accordingly, we recommend the following:

(1) Colleges and universities admit students after high school who might well not appear in a classroom for a year or more after admission. Furthermore, students should be encouraged to stop out for a time to work and reassess their direction.

(2) Consistent with stopping out, co-op or work programs should be developed which actually provide a work experience which is educationally relevant. This is especially important--those programs which actually achieve a cross-fertilization between education and work will transform both students and faculty.

Although in the short run, changes in the educational needs and expectations of younger students will be most relevant for colleges and universities, we believe that in the long run (10 to 20 years), the recurrent education of adults will cause the greatest changes in these institutions. Alone, in terms of numbers, the adult will have a significant impact. For example, the Carnegie Commission estimates from the British experience that Open University in the U.S. would add 250,000 to 350,000 more adult students by 1980 (between 80,000 and 130,000 FTE) [11]. We consider this to be the minimum level of new adult education expected by 1980. As it becomes more widely recognized that voluntary adult recurrent education uses educational resources more efficently than does the traditional "front-load" model, we expect a large increase in the number of adults eager for post-secondary education and a corresponding increase in funding for that education, probably to some degree at the expense of traditional education. Accordingly, we recommend the following:

(1) Colleges and industries actively recruit adults as students by (a) changing admission policies, (b) developing part-time programs which nevertheless are career-oriented and equal in quality and prestige to regular programs.

(2) In addition, colleges and universities should use the new technology which is now available (Appendix 3) to deliver regular instructional material off-campus.

One interesting program which might be a model is that which Jim Gibbons of the Stanford Electrical Engineering Department is conducting with the Hewlett-Packard Corporation. About 20 H-P employees, all with B.S. degrees, but some who would not be regularly admitted on the basis of their undergraduate achievements, are enrolled as masters candidates at Stanford. These employees are based 100 miles away at Santa Rosa and receive each week's material by videotape. A unique feature of their instruction is that each student is a part of a group of not more than 7 which watches the tape together under the guidance of a lay tutor--another H-P employee who usually has some advanced knowledge in the area of the course. The students do the exercises required of all students and come to Stanford for a midterm and final examination. Gibbons reports that their performance is excellent, for some far above what would be predicted on the basis of their undergraduate grades and their GRE scores. Evidently, off-campus instruction can be at least as effective as on campus instruction if the off-campus student is involved in a small earning group which informs, supports, and motivates him.

Gibbons reports that Stanford benefits in at least two ways from this arrangement: the students actually pay quite high tuition fees (although the cost of taping, tapes, videotape machines, etc. is born entirely by H-P) and they have developed demonstrations with H-P equipment and expertise which are now used in the classroom at Stanford.

We believe that it should be possible for most engineering departments to develop this kind of relationship with industry within their sphere of influence, to the mutual benefit of industry, the adult student, and the academic institution.

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Appendix 3

COMPENDIUM ON TEACHING TECHNIQUES

This compendium discusses nine different teaching techniques. The purpose and function of each are given, as well as its merits and drawbacks. Learning theories behind each technique, the method of implementation, and the cost are given as far as this is possible today. The nine methods discussed are:

Lectures
Personalized System of Instruction (PSI)
Laboratory Instruction
Guided Design
Seminars
Tutorials
Case Method
Computer Aided Instruction (CAI)
Projects

A. Lectures

1. Purpose

The lecture method can be described as a way of "batch processing" students in large numbers through the course content. This is the traditional way of instruction in the majority of engineering courses. The enrolled students are assembled in a large room to listen to the oral, visual, and blackboard delivery of an instructor who, at least within the level of the course, is a master of the subject content. The rate at which material is covered approximately equals the rate at which the lecturer can work his way through the material; thus, all participants, students, and lecturer alike, will work their way through the content of the course in identical time-schedules. The main goal of the lecture method is to complete the assigned course syllabus, thus insuring that the course content has been adequately covered. A skilled lecturer can vividly demonstrate for the students how someone accomplished in the field thinks about the subject. Motivation factors can be built into the time frame of the class period in such a fashion as to model professional behavior before the student.

When the lecture method is broadened to include discussion, thereby forming the lecture-discussion method, a skilled instructor can produce an exciting class experience of exceptional quality. While the lecture itself is strictly a talk with intense active involvement on the part of the instructor, lecture-discussion is a highly flexible, quasi-lecture format that involves a significant percentage of the students in equally active participation. Questions and answers, short micro-dialogues between the instructor and a few students, and other forms of informal communication become nearly as important as course content itself.

The lecture method works well in situations where it is essential to bring before the class recently reported experimental or theoretical data or ideas which were only just conceived by the instructor. The method lends itself easily to using technical teaching aides--slides, movies, overhead projectors, even audio and video tapes--and when these are woven into the course presentation along with guest speakers, the course can be maintained at high levels of currency and relevance.

2. Learning Theories

The lecture method is a "natural" way to teach--that is, it is obvious that if an authority on a subject is available, people will assemble to hear him address the subject. Witness the large number of lecture series on a college campus. Precisely because it is so "natural," it is presumptuous to ascribe to it any formal learning theory based on the scientific work of learning psychologists. However, motivation factors can be integrated into the lecture approach particularly as that method is broadened to become lecture-discussion. Showing personal relevance to his learning tasks, using tests as diagnostic learning aids, and carefully defining for the student what is important and what is expected of him, are psychologically sound ways of incorporating the results of learning theorists into the lecture method.

3. Implementation

Several obvious requirements of a lecture course are: that students have enrolled, that an instructor is available who has demonstrated ability/knowledge in the content of the subject (or at least closely related subjects), and that a room large enough to accommodate the number of students enrolled in the course be available. Depending on the style of the lecturer, a spectrum of teaching aids may be needed; for instance, a large front-of-the-room blackboard with an ample supply of chalk, overhead, slide and movie projectors, audio and video tape playback units, and demonstration apparatus.

Typically, to develop a lecture course, one must first decide what content one wants to cover. Next, a course outline or syllabus listing in detail both the content areas and the schedule must be formulated. While working on these initial tasks, one may want to begin a search for a textbook to accompany the course. Many times the text itself will determine in part the details of the course syllabus.

Students will want to know the course "rules" early in the semester, so one will have to be prepared at the first class meeting with some of these administrative details. The kind of examinations--fill-in, multiple choice, essay, problem solving (both routine textbook type and the more sophisticated open-ended type)--as well as the number and weighting of examinations, should be explained when the semester begins. The role of homework and the final examination in the determination of the student's course grade should be specified. Finally, when laboratory work is an integral part of the course, one should make a joint policy with the laboratory instructor on the contribution that the student's efforts in the laboratory will have toward his semester grade. The motivational advantages of these seemingly trivial details of foresight on the lecturer's part cannot be overemphasized.

The lecture method is readily adapted to industrial extension by TV network or video tape.

4. Costs

The cost analysis technique of accounting for teaching probably has its origins in the lecture method. It is common to assign a fraction of the lecturer's salary to the course and then to divide this dollar value by the number of student-credit-hours (the number of students multiplied by the number of quarter-credits carried by the course in the registrar's role).

Conventional Lecture: Classroom Delivery

Faculty gives lecture to class 4 hrs/wk; TA meets with students in 5 small groups of 20 students each for 2 hrs/wk. The course carries 4 units of credit.

Operating:	Faculty 1/3 time for 3 mos. @ $2k/mo.		$2.0k
	TA for 3 mos. @ $400/mo.		1.2k
		Total Dollars	$3.2k
		UNIT COSTS (3.2k/400)	$8/student-credit-hour

Conventional Lecture: Live TV Transmission to Off-Campus Locations

In class TV facility for live transmission to local industrial and other pre-paid subscribers

Company Costs:	Receiving Station TV monitors		$9.0k
University Costs:	Capital equipment		
	Initial capital investment of central studio and transmitter at the university		$1.2M
	Operating costs		
	Lecturer @ $50/hr for 40 hrs		$2.0k
	TV operating costs (not including equip. amortization) @ $50/hr		2.0k
	Homework grading		0.6k
		Sub-total	$4.6k/ course

20% yearly amortization of $1.2M capital investment, assuming 4 channels used 30 hrs/wk for 40 wks/yr	2.0k/ course
Total Dollars	$6.6k/ course
UNIT COSTS ($6.6k/400)	$16.5/ student-credit-hour

Conventional Lecture: Video Taped in Classroom

Conventional lecture format using video taped lectures mailed or hand-carried to off-campus location. Questions are answered by telephone immediately after viewing the tape. Instructor personally visits off-campus class twice during the term of the course.

Company Costs:	Start-up	
	Video Tape Player	$1.3k
	TV monitor for each 20 students	0.6k
	Reusable Tapes @ $60/hr for 40 hrs	2.4k
	Total Dollars	$4.3k
University Costs:	Operating	
	Lecturer @ $50/hr for 40 hrs	$2.0k
	TV Taping @ $50/hr (includes amortization of TV studio and equipment, but not of classroom equipment)	2.0k
	Tape distribution and grading homework @ $6/student with 100 students	0.6k
	Total Dollars	$4.6k
	UNIT COSTS ($4.6k/400)	$11.5/ student-credit-hour

5. Merits

a. Faculty

Since the lecture and lecture-discussion methods are so pervasive in American engineering education, the approach must have advantages. Most engineering educators received their own technical education largely through lectures; we are thus intimately aware of its benefits. First of all, it conveys a sense of the guiding principles of a body of material, as well as the material itself. Secondly, the routine lecture is relatively easy to prepare; as a rule, only a couple of hours effort must be expended in the preparation of a one-hour lecture. While this may not be completely true for the beginning instructor, it is reasonably accurate for the experienced lecturer. The comprehensive multi-media lecture presentation obviously needs considerable lead-time for preparation, but the more typical "chalk-talk" type of lecture can be put together the day of the scheduled class period if need be.

The rate at which material is covered usually is an estimate on the instructor's part of the rate at which the average student can learn the material effectively. The rate of presentation can easily be adjusted to the level of difficulty of the material and to how well the class is absorbing the technical content. An outstanding feature of this method of teaching is that impromptu materials can be incorporated easily into the body of the course by the instructor; in fact, this can often relieve the steady drone of the routine lecture presentation. The competent lecturer is also a positive model of the traditional teaching/learning complex for the student. This is an often overlooked but important advantage of the lecture method.

The lecture method may appeal particularly to the instructor who has just recently earned his doctorate, probably because it gives him considerable satisfaction to display in a public forum his considerable knowledge and skill. At the other end of the professional spectrum, the method is readily employed by scholar-teachers with international research reputations, probably for many of the same reasons. Most university level professors of engineering fall between these two boundaries.

b. Students

Lectured classes can be an enjoyable experience, particularly if the instructor is good at his craft. He may be quite a showman. The student may enjoy the performance as much as he enjoys learning the content of the subject. The instructor's sense of humor may be entertaining, his apparent knowledge of the subject and its relationship to related subject fields impressive, and he may represent a professional subject model with which the student can identify. These things will be especially true if one is a strong student, whether one is just beginning his college studies, or whether one is completing his doctorate coursework. Weak students, however, may find themselves drawn into the content of the course by close personal identification with the instructor, assuming that such interpersonal relationship is encouraged by the instructor.

The student is usually graded on the basis of several hour exams, probably some homework, and the final exam given at term's end. The course outline usually specifies the rules by which the student will earn the grade for the course. If he finds that the lecturer goes too fast for him to absorb most of the subject content as it is being presented, the student may seek advice from his lecturer on ways to improve his rate of absorption, as the lecturer has committed himself in his syllabus to cover a set amount of material content by term's end. If, on the other hand, the pace of the lecturer is too slow for the student--either because he has pre-experience with the subject, or because he is one of the brighter ones in the class, he will not find it easy to get the instructor to move along any faster, for the lecturer must aim at the average learner. However, in most schools, the student has the option of electing not to attend the lecture.

The obvious disadvantages of the lecture method are its inherently one-way nature, its overuse, and its intellectual dishonesty. The lecturer, especially the poorly-prepared or unconfident lecturer, may tend not to allow class input and may proceed in a purely transmitting mode. This, together with the saturation use of the lecture in most schools, will cause a loss of student attention. Minds will wander, notes will be neglected, and attention will drop. In most lectures, it is apparent that some of the students are "tuned out" at any one time, a situation which is inefficient for learning and deleterious to the morale of the instructor.

The intellectual dishonesty is a more subtle problem. A lecture is usually a logical, efficient distillation of well-researched and documented material. It does not reflect the uncertainty, the blind alleys, the groping, and the frustration that accompanies the finding of new understanding and new knowledge. Neither is it representative of engineering practice, where the professional usually works in an environment where knowledge is incomplete. The lecture therefore presents an overly polished impression of knowledge, and has been blamed repeatedly for the lack of technical perspective which engineering students seem to have when they meet their first engineering jobs.

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B. PSI/Keller Plan

1. Purpose

The purpose of "personalizing" a course via the Keller Plan is to increase the probability of a student mastering the content of subject material while using the faculty more creatively and effectively. This method was originated in 1964 by Dr. F. Keller, a learning psychologist. (The approach is frequently confused with Programmed Instruction, PI. PSI stands for Personalized System of Instruction. In order not to confuse the programmed idea with the personalized approach, the term IPI, Individually Prescribed Instruction, is sometimes employed. However, it is frequently used to designate a host of individualized formats of which PSI is but the major one, so it is wise not to simply equate the two abbreviations.)

Five features are commonly ascribed to this learning system: (1) it is individually paced, (2) it is mastery oriented, (3) students are tutored by student proctors, (4) the course is structured around a carefully formulated study guide that includes objectives for each unit, self-assessment questions, and carefully stated reference materials, and finally, (5) lectures are used as motivators.

2. Learning Theories

The Keller Plan employs behavioristic theories of learning. Two key concepts are: immediate reward for correctly learned material with immediate assistance being available for material incorrectly learned the first time (reinforcement), and, secondly, a well-defined procedure for attaining a high grade (motivation).

3. Implementation

Two distinct kinds of efforts may be required to implement a course to the PSI format--those of origination and maintenance. If you intend to transform your course into the Keller Plan format by originating or writing the materials yourself, your task will be similar to that of writing a small textbook. The steps are roughly as follows: (1) select a standard textbook in the field, (2) arrange the chapters of this text into well-defined small instructional units, (3) prepare instructional objectives for each unit in the form of behavioral outcomes which are measurable with quizzes, (4) prepare supplemental reading material to emphasize selections or sections in the text to which your study guide is keyed, (5) prepare study guides which structure the student's way through the course in a well-defined manner, (6) prepare a battery of quizzes (several of the same level of difficulty) for each unit of material to be covered, and finally, (7) select student proctors and determine ways in which they will be paid. The work involved is sufficiently time-consuming to warrant "released time" from other duties. In short, there is a high initial set-up cost in preparing original PSI materials. You should also be aware that the Keller Plan has apparently found its most effective use in "factual" courses, and that there is considerable question of its appropriateness for courses where judgement is needed--e.g., design courses or laboratory courses. [To extend the approach to make room for communication (reports, presentations, judgements, and the like), may in fact be a promising research area.] If your course is approaching steady-state, you may find it wise to prepare a new set of quizzes each time it is offered.

Once the course has been transformed to the Keller format--either by yourself, an in-house colleague, or someone outside your school, the effort required to maintain the course is comparable to that normally associated with running a lecture course that you have taught before. Unlike the standard lecture course, the quality of a course that has been personalized may continually be upgraded by devoting that portion of your time normally spent on lecture preparation to refining objectives, preparing more effective supplemental reading material, refining quizzes, preparing video and audio augmentations to the main reading material, and working with those students for whom the proctors may not be appropriate, namely, the very slow and the very bright. In situations where the number of students involved do not warrant student proctors, the instructor himself can do the tutoring, thereby giving essentially private, but very well-defined lessons in the subject. For small institutions (such as "inner colleges" within large state universities or the small private liberal arts college), this allows producing courses of high quality with low course production costs.

4. Costs

The variables of cost in PSI courses are more diverse than those for a traditional lecture mode, but the following points seem clear. If you must set up the PSI course and charge for your labors, you will find this method expensive. A not uncommon situation in the academic world, is that the instructor donates his effort. Straight operational costs of the personalized course, however, are probably less than those associated with lecture courses.

Conventional PSI

Start-up:	Faculty for 3 mos. @ $2k/mo.	$ 6k/course
Operating:	Faculty 1/3 time for 3 mos. @	2k
	1 proctor for each 10 students @ 200 each	2k
	Amortization of set-up costs 4 offerings/yr × 5 yrs	300/course
	Total Dollars	$4.3k
	UNIT COSTS	$10.75/student-credit-hour

PSI with Audio-Tutorial

Uses audio cassette tapes plus study guides and slides. Questions answered by proctors, assistants, faculty. Tests administered by staff.

Preparation of slides	$0.2k
Capital, slides-tape carrels	0.5k
Operating costs for 100 students (same as conventional PSI)	10.75/student-credit-hour
Preparation of slides and tapes 1 mo. salary @ $2k/mo.	2k
Capital costs: 2 slide-tape carrels @ $0.5k	1.0k
Total Dollars	$3k
Amortization of equipment and production costs over 5 yrs with 4 courses/yr	$150/course
Incremental unit costs due to addition of audio-tutorial method to PSI	0.38/student-credit-hour

UNIT COSTS:

Conventional PSI course	$10.75/student-credit-hour
PSI with Audio-Tutorial	$11.14/student-credit-hour

PSI with Video-Tape Supplement

Use short 20 min. video tapes to provide demonstration, perspective, and motivation. Otherwise, course is administered in conventional way of personalized courses. PSI study guides used for independent study. Questions answered by staff of proctors, assistants, and faculty. Tests administered by staff.

Start-up costs:	
TV production costs 5 hrs @ $1.5k/hr	$7.5k
Remote location:	
Group of 100 students in one location	
15-20 min. classroom tapes @ 25	.4k
Video tape player and monitor	1.7k
Sub-Total	$2.1k
Total Dollars	$9.6k
Amortization of equipment and production costs over 20 course offerings in 5 yrs	$0.48/course

Incremental unit costs due to addition of TV supplement		$1.2/student-credit-hour
	UNIT COSTS:	
	Conventional PSI course	$10.75/student-credit-hour
	TV supplemented PSI	$11.95/student-credit-hour

5. Merits and Disadvantages

a. Faculty (Originator)

The principal advantage to preparing a Keller format course is that it places the teaching of the course out into the "open"--in precisely the same way in which laboratory research is conducted in the open--thereby making it possible for the student to know exactly what is expected of him, to study at his own speed and at times when he learns best, and to take tests when he is ready for them. The advantage for faculty is that the conduct of the course can be examined objectively. It allows ready comparison between courses purporting to teach identical material to students.

Because the vast majority of courses are lectured, the preparation of a course in the PSI format is still novel and not widespread. Implementation of a Keller plan will naturally attra[illegible] attention to your learning/teaching research and to your effort [illegible]rove your teaching effectiveness. Thus, your image as a dedicat[illegible]cher will rise. This rise in teaching reputation is often so pronounced that if your principal activity for years has been research, you may want to seriously consider Kellerizing a course. By so doing, you can not only present and publish papers on the content of the course, but also on its delivery and evaluation.

The most obvious disadvantage of originating a Keller Plan course is the risk of failure associated with a new venture. Because the course is "open" in the sense that instruction does not take place behind the closed doors of a lecture hall, Deans, Chairmen, and fellow faculty can view the course and will not need to wait several semesters before assessing the quality of your teaching. If you are a weak teacher, this is obviously to your disadvantage. An additional psychological difficulty for the instructor can arise from the fact that Keller Plan courses are not teacher-centered; and, hence, the instructor is not "on stage" before a captive audience as in a lecture class. If lecturing is an "ego trip" for you, you may miss performing on stage.

As the class format is overwhelmingly a written one requiring effort vastly exceeding lecture preparation, a considerable disadvantage in setting up a Keller format course is the additional time required. Not only must you have technical maturity in the field of the course, but you must also have solid mastery of the specific subject content itself. This contrasts with lecturing where it is commonly recognized that preparing lectures is a first rate way through which the instructor can teach himself the technical content of an unfamiliar course.

Research directed toward the effectiveness of the Keller Plan is important, for much remains to be investigated and reported in easily usable form. The difficulty of student procrastination alone, merits careful thought. Should reasonable solutions be found that are as easily implemented as the course itself, wide dissemination of Kellerized courses through publication would be possible. The possibility of casting the Keller course into an audio-video format may even satisfy the "ego trip" similar to lecturing. And, because content delivery is now in the hands of the student himself, learning can be facilitated for a broad spectrum of students, both the very bright and the not-so-bright in a one-to-one tutorial situation.

The advantages to the faculty member giving a PSI course resemble those for the faculty-originator.

The possibility of offering a course of high quality at low production costs is especially attractive for small schools. The capability of "private lessons" in the course is also a drawing point in the small institution where enrollment may not warrant the costs of student proctors. The important advantage to instructors in large institutions is that the course can be managed as effectively as a lectured course, but with less effort and time. As the course runs itself, you may gain released time for other pursuits.

b. Students

Keller-formated courses force the student to make decisions on his own and to know himself well enough to sense when he is in trouble with the course content. The course is structured so that the student cannot be a passive learner. Content will come by the written word, as contrasted with the spoken delivery in lecture courses. Thus, the student must be able to read and to follow directions. Because various learning materials will be available to the student in noncentralized locations, he must be mature enough to use these materials without relying on explicit commands.

A serious disadvantage of enrollment in a Keller format course is that the plan may not have been implemented very well and the student runs the risk of investing a semester's effort in a course whose instructional format is ill concieved. But, students run this risk in lecture classes also. Assuming, however, that the course has been implemented well, the student's principal difficulty, if any, is that he must move through the course on his own. Help is available from the instructor as well as from the student tutors; however, Keller format courses are self-paced. It may be tempting to procrastinate, especially if other courses have strictly schedule assignments. The student must determine a place other than the normal classroom for optimal learning--the living quarters, the library, the coffee shop, the tutor's room, etc.

It sounds threatening, doesn't it? What then are the advantages that would lead the student to enroll in a Keller format course? Only two are significant, but they are persuasive and compelling. First, he can determine by himself how high a grade he will earn for the term's effort. He is in control. As a rule, he will learn more and work harder than in a standard lecture course. He will find it relatively easy to work to his fullest potential. The system will pull the student along, enabling him to perform better than he would have thought possible from his experience in standard lecture courses.

The second advantage is a free and flexible schedule. The student does not attend lectures. In fact, no learning activity is prescheduled. The student self-schedules learning activities himself. This can be an enormous advantage if he is involved in extra-curricular activities such as athletics, a part-time job, and so forth. The student may average about an hour per day studying the reading material, working through self-assessment problems, taking quizzes, or working with either the student proctors or his professor. However, he can do almost any of these activities at times which are convenient for him. He can work ahead for recreation, and he will be able to finish the term early if he desires, thereby making more time available for other end-of-term studies.

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C. Laboratory Instruction

1. Purpose

The engineering laboratory is unique within engineering education. Laboratory education is participatory. Students must use many skills--verbal, written, and manipulatory. Basically, there are six objectives which are commonly incorporated within laboratory instruction: (1) equipment familiarization, (2) model identification, (3) validation of assumptions, (4) prediction of the performance of complex systems, (5) testing for compliance with specification, and (6) exploration for new fundamental information. A laboratory should introduce the student to instruments and measurements techniques, provide the analytical background on the design of experiments, and let the student design and perform experiments on his own. The laboratory does not serve only as a means of verification of theory; it puts reality into theory and indicates the limitations of theory in actual situations.

2. Learning Theories

Learning by doing is the basic approach. Thus, the key to successful laboratory oriented studies is active involvement of the learner. Demonstrations by the instructor do not develop the student as an experimenter. The laboratory experience must be structured in ways that place the student in an active role.

3. Implementation

A clear understanding of your goals for laboratory instruction must be developed before you implement such a course. Experiments designed to teach instrument familiarization and those aimed at developing experimental ability will differ. Since few formal texts in experimental design are available, a set of handout notes will probably need to be developed to accompany each experiment of the course.

Central to the implementation of laboratory orientated studies, is the concern with laboratory equipment and apparatus--where does it come from, how much is needed, how much duplication is required? The way you schedule your laboratory sections determines the answers to these questions. If you must "batch process" a class of 20 students in five 4-member teams, you will need five identical sets of equipment. This has been the traditional mode of operation used in laboratory instruction. In a laboratory conducted in this manner, the utilization factor (% time in actual use) will be low, for the equipment is not used except during scheduled classes. One simple way to attain a higher utilization factor is to arrange the experiments that accompany two different courses so that commonly used instruments (such as oscilloscopes, xy recorders, thermometry apparatus, and the like) can be used in one course when the other is not scheduled. Thus, you may be able to acquire a basic set of high quality instruments and apparatus that may be useful in more than one course, thus achieving an overall lower cost of equipment per course.

However, you may want to run your laboratory course totally on an "open shop" or "time-shared" basis. The student sees the laboratory as being available to him in much the same way in which the university library is available to him--on demand. Under the open shop policy, students are permitted to work in the laboratory at any time during the normal class day; the class as a whole is not prescheduled. The students will be distributed both in the times of the day at which they find it most efficient to work through the assigned laboratory tasks and in the amount of time on a given set of apparatus necessary for them to achieve the stated goals of a certain experiment. You may discover that you need less duplication of equipment, and your equipment budget dollars can be used to acquire a broader range of instruments and components, knowing that the utilization factor will be high on every major piece of equipment.

You can evaluate student performance in several ways. Four techniques which have been used widely are lab notebooks, formal laboratory reports, written examinations on data in lab notebooks, and laboratory performance examinations.

The lab notebook is an experiment-by-experiment assemblage of approaches, data, and tentative conclusions; it resembles a research journal or patent notebook. It tends to be rather informal in composition, but at the same time, it gives the student practice in a widely-used industrial procedure. Formal laboratory reports, on the other hand, are similar to "papers" on the assigned experiment. They are an excellent means of teaching students the rudiments of technical writing; however, they do require large investments of time beyond the experiment itself. You can also give examinations on the data that appear in a lab notebook. This can motivate the student to be thoughtful with what he enters into his notebook. Finally, laboratory performance examination is similar to the road test of a drivers examination in that simple experiments are assembled at the end of a unit of study for the student to demonstrate in your presence that he can "do the experiment."

In summary, to implement a course of laboratory instruction, you will need to (1) decide upon your course objectives, (2) prepare "notes" (written, audio or video tapes) to present the essentials of the experiment to the student, (3) structure the class in either the prescheduled or the open shop mode, (4) allocate appropriate budget dollars for the acquisition for amortization of equipment, and finally (5) decide upon the technique for evaluation of student performance.

4. Costs

The laboratory course considered here is a 4 qrt. credit hour course (1 hr lecture, 9 laboratory hrs/wk) for 100 students. These numerical examples are typical of an introductory electronics laboratory.

Start-up:	Faculty 1/3 time for 3 mos. @ \$2k/mo.	\$2.0k
	Technician full time for 3 mos. @ \$0.8k/mo.	2.4k
	Equipment \$3k/team × 50 teams	150.0k
	Total Dollars	\$157.4k
Operating:	Equipment amortization 10%/yr, 10 labs/yr	\$1.5k
	Supplies \$10/team × 50 teams	0.5k
	Faculty supervision 1/3 time for 3 mos. @ \$2k/mo	2.0k
	10 hrs TA time for each 12 students requires 4 TAs @ \$400/mo for 3 mos	4.8k
	Technician 1/2 time for 3 mos. @ \$0.8k/mo.	1.2k
	Total Dollars	\$10.0k
	UNIT COSTS (10.0k/400)	\$25/student-credit-hour

5. Merits

a. Faculty

It is said that while the instructor controls a regular class (particularly a lectured course), the student is in control in the laboratory. If you feel uneasy about not having all the answers readily at your finger tips and at interacting with students in an informal manner, you may feel at a disadvantage in a laboratory course. The time and effort required to produce quality laboratory instruction and experimental design are considerable. Unquestionably, there are institutions where such efforts may not be rewarded proportionately; but we should point out that frequently it is possible to inspire good students to help you do your experimental research.

b. Students

The student will find well-run laboratory oriented studies to be motivating experience as they are opportunities to relate abstract engineering analysis and design to hardware and real-life situations. He will have "hands on" experience with engineering instruments and equipment, and thus he may at last see the point of much of the theoretical development that was so heavily emphasized in lecture classes. If the student has come into engineering with considerable practical knowledge, he can look forward to rapid growth and technical maturity as he builds upon this technological base. On the other hand, should the theoretical and design aspects of engineering have originally attracted the student into engineering studies, the laboratory experience will contribute to his overall grasp of the modern aspects of engineering practice. In either case, laboratory learning will be more open-ended, less directed in the sometimes trivial ways of textbook homework assignments, and more dependent upon the student's own initiative and imagination.

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D. Guided Design

1. Purpose

Guided design is part attitude, part content delivery, and part system. It is based on a connected series of goals: to provide training in solving professional engineering problems, to teach students how to think like an engineer thinks, to increase his motivation to learn, to provide training in open-ended problem-solving which face our society, and to develop positive values in contributions made by the engineering profession to society.

In operation, Guided Design is a way of structuring course work to provide training and experience in the evaluation of open-ended problems. In playing the role of a professional engineer, the students come to see that professionals accomplish worthwhile things in helping people to live better lives.

Students are guided through a series of problem-situations by way of a series of Instruction-Feedback pages which resemble those commonly used in Programmed Instruction (PI). The usual format in a PI frame, however, is short with the intended result being a short numerical answer, while in Guided Design, each frame is more comprehensive and involves larger steps. Students develop their collective response to each frame in small group discussion and then are given the opportunity of comparing their step solution with that which probably was developed by a professional engineer, by studying the printed Feedback statement.

Each open-ended problem situation is structured by the instructor to guide the student into realizing that he needs a unit of technical knowledge before he can proceed. The student is expected to learn technical subject content on his own outside of class through such learning devices as texts, audio-tutorial, or programmed instruction (PI). Class time itself is devoted to small group discussions of the project steps or to a search for required technical information. The instructor's role is to assist this learning process, but not to specify it or to hand it out.

2. Learning Theories

The educational principle of active involvement of the learner is the main learning theory employed in this approach. The approach is a form of the Socratic method, and, as such, the following are central:

it guides the student as he learns, it reinforces the student as he makes his choice of answers, and it motivates the student through encouragement.

3. Implementation

To cast a course into the Guided Design format, you will need to become familiar with the term Design in its broad socio-technological sense as the interactive decision making process by which scientific, technological, economic, and social factors are combined to transform resources into systems and devices which satisfy desired human needs. While the conventional technical course emphasizes the transmission of subject content, Guided Design is a format which does that in the process of accomplishing larger goals. It teaches the student to solve open-ended problems, make decisions, communicate ideas, and use the intellectual modes of analysis, synthesis, and evaluation.

In casting your course into the Guided Design format, you may want to explore such ideas as: (a) emphasizing the development of good decision-making skills, (b) creating a need to know that parallels the professional engineer's desire to "get the job done," (c) the establishment of instructional objectives, (d) testing based upon performance objectives, and (e) the concept of mastery learning.

The name Guided Design comes from the series of printed "Instruction and Feedback" statements which resemble the "frames" in Programmed Instruction. These printed statements help the student learn how to proceed through the decision-making process in seeking solutions to open-ended problems.

After you decide to employ guided design, you should consider whether a single course is worth casting into the guided design format, or whether a department-wide enterprize and curriculum change is merited. The practicalities of producing a wide-scale guided design curriculum are many, and the problems have been tackled by others with success.

4. Costs

If you decide that you will originate an effort on your campus in guided design, you will probably require released time, at least in the beginning. You may well not encounter costs any higher than those normally associated with lecture/discussion courses, should your goal be to put into operation that which others have already accomplished.

Grants for the purpose of implementing a course into guided design are available (see References).

Start-up:	Write set of Instruction-Feedback Statements (similar to preparing a PI textbook)	
	9 mos. faculty salary @ $2k/mo.	$18k

Operating:	Faculty supervisor 1/3 time for 3 mos. @ $2k/mo.	2k
	40 hrs/wk TA requires 2 TAs @ $400/mo. for 3 mos.	2.4k
	Total Dollars	$4.4k/ course
	UNIT COSTS ($4.4k/400)	$11/student-credit-hour

5. Merit.

A distinct advantage of Guided Design is the ability to evaluate each step in a decision process clearly and objectively. Because the students are active, rather than passive learners, their motivation is high, and as a result, faculty enthusiasm also remains high. However, the open-ended nature of the problem-situations is so different that you may have difficulty visualizing your role as the instructor. Subject content is important in guided design, but because the emphasis on content is so nontraditional, you may encounter problems with the reputation of the course among faculty peers.

A definite advantage to this approach is that it may be applied to courses other than just those in engineering which likewise address the socio-technical interface. It has been used successfully in freshman engineering, chemical engineering and chemistry, mechanics, environmental education, rehabilitation counseling, wildlife management, history of drama, and educational psychology. It may offer an interesting approach to a joint offering that an engineering department, a science department, and a humanities department can put together in the area of Science, Technology, and Values.

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E. Seminar

1. Purpose

The purposes of a seminar format are to share the contributions that all students bring to the class, to assist the student in learning to make oral presentations, to help students learn to work as a group, jointly discovering and relating new material. The seminar or discussion group is a time-honored technique; its format requires maturity from both students and faculty.

2. Learning Theories

Active involvement on the part of the student should make an active learner. We learn what we do. But, this approach accomplishes little unless the students are indeed active, willing participants; it will do them little good to just "sit and listen."

3. Implementation

To implement a seminar requires a good deal of experience in working with students or at least the first-hand knowledge of having gone through a successful seminar yourself. Besides the obvious library or resource materials required, the only special requirements are physical surroundings conveniently designed for the conversational mode of seminars. The usual mental image is of a round table equipped with comfortable chairs.

4. Costs

The calculation of costs would be done in precisely the same manner applied to ordinary lectured classes: i.e., faculty salary fraction (plus a % for overhead) divided by student-credit-hours delivered.

Operating:	Break 100 students into 5 sections of 20 students each 5 faculty each 1/3 time for 3 mos. @ $2k/mo.	$10k/course
	UNIT COSTS ($10k/400)	$25/student-credit-hour

5. Merits

a. Faculty

As a faculty member assigned to teach a seminar, you may not need to expend the high intensity of presentation during class that you would in a lecture, since the students will carry most of the burden. Because the seminar format encourages openness, trust, and person-to-person interaction, you may develop a special kinship with the class. You may become receptive to branching in directions that may not have occurred to either you or to the students at the term's beginning. For advanced graduate work, the seminar still remains the single most effective way to get research students to set forth their latest findings. In such a context, your rate of learning during the seminar itself can be higher than the students'.

On the negative side, especially at the lower division undergraduate level, you may find many students unprepared for a discussion format. In such cases, the structured seminar may be appropriate if you are irreversably committed to the seminar mode. However, unless you have assembled ample resource materials--reference texts, journal articles, slides, tapes, external speakers, movies, field trips--prior to the term's beginning, you may find it impossible to get the students into the body of the material rapidly and effectively.

b. Students

If the student has something to say on the subject, if he has a position which can be championed and presented to his peers in a persuasive manner, and if he enjoys a "verbal" type of exchange, then he will delight in a seminar/discussion course. Without doubt, the seminar has the unique advantage that it can be structured to meet the needs, objectives, aspirations, interests, and even life-style of its participants. The student will get practice in setting out his thoughts before a group of his peers and will receive the benefits of having to "think on his feet." He will come to know first hand something of group dynamics and how a group discussion can be dominated. He will also see how easy it is to get side-tracked. The instructor will be a live model against which the student may judge personal and professional growth.

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F. Tutorial

1. Purpose

A tutorial course exposes the student to subject material in a one-on-one situation with his instructor. It is a mode of instruction best represented by the "private lesson" approach to learning, having no set format or delivery technique. The only common prerequisite is a master (the instructor), an interested student, and subject material of mutual interest.

As old as western civilization itself, the technique has roots at least as far back as Plato in ancient Greece. However, it is as contemporary as any current teaching method, appearing in most engineering programs as "independent study." To this day, it forms the fundamental approach used in thesis research for advanced degrees, particularly the doctorate. It is the type of instructional situation which a great many students envision college being; but find, of course, that, at best, it is used in honors programs or in advanced graduate work. It also surfaces in remedial programs.

2. Learning Theories

Tutorial learning provides a positive reinforcement for the student involved, the learner having his efforts reviewed personally by the master. However, it should be realized that the reinforcement is not always immediate; tutoring sessions may occur but once a week or even more infrequently.

3. Implementation

Implementing tutorial or independent study courses requires a motivated student, an interested professor, and a mutually agreed upon subject of inquiry. Beyond these, however, the requirements are chiefly those of maturity on the part of both participants, willingness for both to work in a one-on-one situation, and mutual respect.

4. Costs

At the graduate level, costs of this type of instruction are calculated as faculty salary fraction per student credit hour. Because graduate faculty are usually the highest paid faculty and because the number of students enrolled in thesis research is small, the costs of this type of instruction are among the highest.

At the undergraduate level, independent study courses are usually not figured into an instructor's load; that is, he does them on an over-load, unpaid basis. As a result, there are no costs assigned to the departmental budget for these teaching duties. In situations where large numbers of underprepared students require tutoring in a formalized remedial sense, however, costs would be calculated as above.

Operating:	Each full-time faculty member can teach 12.5 students For 100 students, 8 full-time faculty are required @ \$2k/mo. for 3 months	\$48k
	UNIT COSTS (\$48k/400)	\$120/student-credit-hour

5. Merits

No one has yet found a substitute for the tutorial concept at the graduate thesis level; and as such, its advantages and disadvantages are well understood by all who have been through a difficult thesis preparation. The idea still remains viable.

At the undergraduate level, however, there are distinct advantages to the approach--even faced with the fact that these are "free" lessons. An instructor may be able to identify bright students he can lead via a tutoring course to his own field of endeavor. That is, it may be a way in which the quasi-interested student gains awareness in particular aspects of a given subject field he might not have gained on his own. These tutorial students may, in fact, turn out to be the best advertisement and the best recruitment technique in the academic world for your own personal efforts in teaching.

From the student's point of view, one or two undergraduate tutored courses may become the most influential of his undergraduate career, as he will see his professor frequently in an intimate setting. Seeing the high regard of his professor for the educational process, he may rededicate himself. Thus, it is the process of tutorial instruction that may have a longer lasting effect on the student than the content.

G. Case Method

1. Purpose

The case method brings specific examples of actual engineering practice into the classroom--not examples of how it is said that engineering is practiced, but authentic accounts of engineering design as performed by engineers working in industry. Many engineering cases show the development of the solution as it was worked out on the job. Cases are developed in several sections. The first is usually a descriptive scenario which defines the problem. This may be followed by the first--often unsuccessful--attempt at a solution. Then might come the development of a workable idea, followed perhaps by its execution in practice. To achieve the greatest educational benefit, students are asked first to read only the first part (or parts) of the case and to attempt to solve the problem in their own way. Subsequent reading and class discussion brings out the differences between their solution and that developed in the case and the reason for the differences. The instructor should have a series of questions prepared for each stage of the development of the case to be answered by the students as a homework assignment and/or orally in class.

This approach to instruction brings outside reality inside the classroom. The case method has been around for well over 100 years in legal education and nearly 50 years in professional schools of business, but it was not until 1964 that the approach was initially formulated in engineering education. Distinct from employing conjectural examples, engineering cases show how engineering is actually pacticed in industry.

2. Learning Theories

Learning by specific, well-illustrated, but open-ended examples is the central concept in the case method. Since engineering is difficult to define in general terms, cases bring in instances of real engineering experience. Classroom technique with the case method generally centers on discussion of the case's details and the problems it presents. Motivation, skill in modeling physical situations mathematically, and exercises in making engineering judgements, are vital aspects encountered in teaching with engineering cases.

3. Implementation

Offering a course via the case approach requires either the writing of a collection of cases or the use of cases that have been developed and made available to engineering instruction. The first option requires that you develop an intimate working relationship with several members of the engineering staff at a local industry. Together with these contacts, you would develop the specific technical details for a case in a design situation these engineers themselves have faced and solved. If you plan to devote an entire term to exploring engineering cases with your students, you will need something like one case per week.

The Stanford Case Program has 197 cases available; you may want to review their listings before originating your own cases.

The way you plan to use cases within your course should be studied thoughtfully as you begin to prepare the course. Cases may be employed as reading assignments, background for specific problems, materials for problem formulation, subjects for class discussion, or illustrations of theory. The simplest, though least effective, way of using cases is as reading assignments. However, even in this use, they can help students gain some inkling about the world actually encountered by engineers. The other end of the spectrum of possible uses--the case method--produces its full impact upon students and instructor alike. Your students will have to deal with the frustration and consternation they meet as they struggle to discover the threads of a design process which other engineers had to evolve.

4. Costs

The unit operating costs of the case method will be exactly the same as those associated with a lecture of equal enrollment. Costs of originating cases, however, are related to your experience in case preparation. You should plan to use case studies prepared by others (such as the Stanford case study series) and to produce at most one case for a one-third time effort in a given quarter. It is a slow and meticulous process.

5. Merits

a. Faculty

Originating an engineering case more fully develops your insight into the design aspects of engineering practice as related to your field of specialty. Developing cases, requires contact and work with an engineer in a local industry. Thus, the case can become a conduit through which to increase the professional standing of your department with the engineering community. This professional development and the mechanism it provides to work with local industry is one of the principle advantages of the case method. Additionally, an engineering case can be counted as part of your publication record as it is a form of creative professional activity quite apart from normal classroom teaching.

Several hundred cases are already systematically available to you, however, for use in classroom study. Your first attempt to incorporate engineering cases into your teaching should therefore begin with a thorough and careful search of existing cases (see references).

b. Students

As opposed to other more abstract and theoretical course work, the case method introduces the student to engineering areas that may not be totally deductive, such as production processes and design operations. It will probably be a learning experience quite unlike that to which the student has been exposed up to this point in his engineering education. He will develop a flexibility of mind. He will be surprised to discover that not all engineering problems lend themselves to a high quality analytical treatment. Real life can be exceedingly complex, and he will learn that searching, hunches, and even hearsay, in some cases, have led to innovative design solutions.

Many students react to their first case with consternation and frustration. And it will require several cases before students begin to appreciate the value of the case method. However, we cannot overemphasize the importance of carefully planned questions and discussions in analyzing each case. A distinct advantage to the case method is that it will demonstrate that problem definition is far more difficult than the deductive step-by-step analysis emphasized in most engineering-science courses. The student will learn to perceive the time-frame history of the efforts that go into arriving at acceptable solutions to authentic real-life engineering problems and will understand what he will face upon graduation. For that reason, this type of learning experience can be an asset in the student's search for employment and for his career.

Finally, if the instructor happens to be developing original cases, the student may be able to acquire special experience in working with him as he cooperates with the engineering staff in a local industry.

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H. Computer-Aided Instruction (CAI)

1. Purpose

The realization that learning can be markedly facilitated by adjusting to the individual learner the scheduling, pace, style, methods of presentation, and sequencing of content material, has led many to see the value of computers in the educational process. Computers can be used as a teacher's aid, for diagnostic testing, and as a prescriber of Individually Prescribed Instruction (IPI); so used, the computer manages the instructional process. Most commonly, computers are employed in the teaching field as giant mathematical calculators, but they also function equally well in nonnumeric information processing and simulations.

Computer-Aided Instruction (CAI) combines the managing function mentioned above and the programmable calculator mode of computers with the presentation of instructional material directly from the computer terminal. CAI can also include computer-controlled audio-visual material, simulation, computation and problem solving capability, plus tutorial dialogues.

2. Learning Theories

CAI, similar to IPI, depends on the Socratic method. The approach relies on behaviorist learning principles. Reinforcement and motivation are key operational concepts.

3. Implementation

Computer-Aided Instruction began in 1958 with the experiments of Gustave Rath and Nancy Anderson. In the last decade, universities, research laboratories, public schools, the armed services, computer companies, and private publishers, have worked extensively to bring CAI into widespread use. Many of these ventures appear to have had limited commercial success, although two large systems remain dominant--the PLATO Project at the University of Illinois, Urbana and the TICCIT Project--a joint venture of the MITRE Corporation and Brigham Young University. Accordingly, more than in any instructional technique presented in this Guide, you should examine carefully the current literature of CAI as well as the operational details of PLATO and TICCIT to fully comprehend its advantages for your own situation. Personal conversations with workers active in this field are imperative before you invest in a large-scale CAI experiment on your campus. The following would be excellent contacts, known to have functioning CAI courseware: the Physics Computer Development Project at the University of California, Irvine; the Ohio State University Medical School; the Stanford University Elementary and Secondary Project: the TICCIT Project at Brigham Young University; and the PLATO Project at the University of Illinois, Urbana.

Several important decisions are prerequisite to venturing into CAI. Time-shared computer terminals must be available. However, if your computer center cannot provide this facility, you may lease terminals for your course. In either case, you should secure terminals which have a graphics capability; this will enable you to employ CAI in ways not possible in other instructional media. While ordinary teletype terminals first come to mind, CRT displays are more flexible, permitting the display of graphics information. The plasma display panel invented in the PLATO project has even a wider range of useful characteristics.

Your choice of terminal is most important to the effectiveness of your CAI system as it must provide a pleasant and efficient interface between the student and the computer. Other terminal characteristics which should also be weighed during selection are: type of alphanumeric display, printing speed, noise, its ability to draw graphs and diagrams, ability of selective erasure, refreshing of the display, and the cost of purchase, lease, and maintenance. Let us look at two specific examples more closely.

The TICCIT terminal comprises a color TV display, a pair of headphones, and a keyboard. This apparatus can display color TV, alphanumerics and line graphics in seven colors, as well as full-color movies. MITRE's TICCIT computer system consists of a pair of minicomputers that can serve 128 terminals, separating foreground (terminal processing) and background (algorithmic processing) tasks into the two minicomputers. Being a mainline system, the on-site TICCIT instructor has his role redefined to include: tutor-counselor, diagnostician, and problem solver for individual students.

The PLATO terminal in contrast is a plasma display panel. This flat panel--which is not a TV tube--consists of two sheets of glass on which are deposited horizontal and vertical transparent electrical conductors, the space between which is filled with neon gas. The gas can be made to glow as bright dots at the intersections of the columns and rows of conductors. Parts of answers can be selectively erased and retyped with this terminal, in addition to the regular alphanumeric and graphic capabilities of the more conventional units. Moving displays are also possible. The PLATO system itself is controlled by a large central scientific computer located in Urbana, Illinois, capable of controlling 4000 terminals within 100 miles of the computer; and it has sufficient computing power and speed to permit the presentation of complex material, responding to input from the terminal within a fraction of a second. An author language called TUTOR has been developed for use with PLATO which enables instructors to easily learn to use the system while developing their own courseware.

If your computer facility can provide professional computer programmers to help you, your cooperative efforts can produce courseware much faster than you could alone. However, experience suggests that unless you yourself have at least some programming training, it will be difficult for the programmers alone to produce the kind of CAI course you might have in mind.

You can develop CAI without going the comprehensive route of either the PLATO or the TICCIT projects. On-line simulation, interactive numerical design work, and man-machine interactions in societal systems are feasible even with computers of modest computing power. As apparent in the literature on CAI, a large percentage of the problems from a user's point of view are associated with the courseware itself--the educational material through which the computer assists in presentation of the course. Consequently, plan to invest at least one third time of your effort in CAI origination to develop a logical well-formulated courseware package or to study courses available to your system. For example, for each 1 hour of student terminal time, you probably will need about 10 hours in courseware development. Preparing CAI materials is not unlike writing a hard-cover textbook; in fact, it is essentially a textbook in a computer-based format.

Central to and more important than any of the above from the user's point of view, is the study of the unique advantages of computer-based instruction. Until CAI costs can be lowered, it should be used only in ways that take advantage of the computer's unique power to generate moving graphic displays as might occur in the dynamics of particles or in the shift of voter returns in response to simulated issues. This feature is only possible with the computer and cannot be realized effectively with any other educational technology.

4. Costs

Cost factors probably more than any other have prevented CAI from being more commercially successful. The National Science Foundation funds PLATO and TICCIT and a number of smaller projects. Their effort is concentrated mainly in community colleges and elementary schools.

There is a wide variance in the price quotes for terminal time alone---ranging between 25¢ to $50 per student/console/hour. The PLATO system appears to be able to offer CAI at approximately $2/hour. This figure represents $6000 for a terminal and $2000 per year for time, storage, and programming aid; it assumes 160 hours per month of student console time spread over 10 months per year.

Beyond hardware costs themselves--terminals, telephone time, computer time--is the cost of producing courseware. Since most instructors wishing to use CAI will find that they want better, more engineering relevant courseware than is currently available commercially, its development costs are heavy. Costs for preparing CAI courseware are roughly equivalent to those expended in writing a good textbook.

5. Merits

CAI can serve many students simultaneously and at varying levels of treatment; that is, it can offer completely individualized instruction to each student. Emphasis is on the learner rather than the teacher. CAI promises to be a learning resource center in education in the same way that libraries are currently centers of knowledge in universities. The computer can let students interact directly with subject matter. CAI can provide drill and practice, tutorial and dialogue interaction, or problem solving and simulation of complex physical, mathematical, and societal phenomena. With graphics capability at the console, the student can follow the "trajectory" as the parameters in any simulation are incremented or changed in response to new models.

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I. Projects

The project is an open-ended multi-answer problem which may range in emphasis from a single part of the engineering process to all of it and which may vary in time from a few hours to years (a Ph.D. dissertation, for example). It is used to motivate the student, to emphasize the importance of or teach the realistic use of analytical techniques, to give the student perspective on the processes that go into engineering problem solving, and to treat portions of the engineering process (need-finding, problem definition, conceptualization, development) that cannot be treated efficiently by more traditional techniques.

Projects are presently being used in many ways in instruction. They are often used to illustrate particular points or to integrate lecture material. They are sometimes used as a quarter-long or year long experience during which the student may proceed from original need through hardware. They may be hypothetical or real (with an outside customer involved). An indication of the scope in projects can be seen in reference 1 (Heinsohn problem collection from case library).

The faculty's role in project work is more that of the consultant and encourager than that of the expert. He must be sympathetic to the mental and emotional processes that occur during the solving of a realistic engineering problem and must be ready to expedite the process as it occurs in his less experienced students. He must be capable of furnishing or finding technical expertise when necessary. However, he can not hope to consistently possess the "best" answer and must be prepared to operate in certain respects in the mode of an engineering manager. His job is to get the best possible performance from his students, not to parade his own virtuosity. He has the additional responsibility of ensuring that the students be constantly aware of the process as it occurs, the reasons for the decisions they make, and the results of their decisions.

1. Learning Theories

Projects involve the active participation of the learner and give him practice in the affective domain. They are experiential and build the student into the risk-reward system, in that with a good choice of project, the student will become emotionally involved with its solution. Projects also present knowledge to the student in a manner more analogous to professional problem solving than he sees in most of his classes. He must learn to define what he needs to know and learn where to go to find it.

Implementation

The most important single factor in the successful use of projects, assuming that the faculty member is competent to operate in this mode, is the initial choice and definition of the problem. The problem must be stated precisely enough so that the student will reach the desired end point in the time available, but yet loosely enough so that he may contribute the maximum amount of divergent thinking and decision making. It must be motivating enough to hold the interest of the student and result in his best performance, but not so consistently glamorous that he receives a dishonest impression of problem solving or the engineering profession. It must be complex enough to involve the student in many variables, but not so complex that the student has difficulty in doing a workmanlike job in solving it. There is widespread use of projects in engineering education, even though the overall usage is much smaller than the use of lectures. It is important in the use of projects to solicit as much student feedback as possible concerning their overall impression of the project, the time they spent, their impression of what they learned, what was important, what was not, etc. It is often difficult for the faculty to judge such quantities alone. A particularly heavy usage of projects is found among those teaching engineering design, since the project is perhaps the most straightforward method of teaching design.

3. Costs

The definition of a project is relatively simple, although in the case of long-term projects, several days may be necessary to properly define the project and gather the necessary initial data. Once the project is under way, the cost of instruction is comparable to that of conventional teaching in engineering schools. It is not possible to interact with as many students as in the lecture method. However, by apportioning one's time between students and making use of groups, it is possible for a faculty member to handle on the order of 25 students in a course which makes heavy use of projects. Outside resource people are relatively easy to find and are quite effective in the project mode of instruction. Contact time with the students is higher, but preparation time during the project is lower. If hardware is to be built, the customer can be convinced to pick up fabrication costs, since he is getting free engineering.

Operating:	Faculty 1/4 time for 3 mos. @ $2k/mo.	$1.5k
	UNIT COSTS ($1.5k/$75)	$20/student-credit-hour

Appendix 4

INDUSTRY SURVEY

As a part of the study underlying this report, we surveyed collaborative programs between industries and schools. As used here, the term "industry" refers to an organization which employs engineers, and therefore includes both commercial enterprises and governmentally funded laboratories. The term "school" refers to universities and colleges which educate engineers.

The primary goals of the survey were to determine the extent to which industry/school interaction is occuring and to assess trends in such interaction. Toward this end, industries and schools were selected on the basis of their proximity to the study base and on the basis of their diversity. The following organizations provided information:

Bechtel Corporation
California State University at Sacramento
City of Palo Alto
College of San Mateo
General Electric Nuclear Energy Division
Hewlett-Packard
Intel
Lawrence Berkeley Laboratory
Lawrence Livermore Laboratory
Lockheed Missiles and Systems Division
Mack Western
Pacific Gas and Electric
Sandia Laboratory, Livermore
Shell Oil
Siltec
Stanford University
Technology Learning Corporation
Texas Instruments
United Airlines
University of California, Berkeley
University of the Pacific

The survey disclosed seven primary formats of industry/school interaction: cooperative work/study programs, continuing education or extension programs, consulting relationships, research programs, design projects, exchanges of personnel, and special programs. This appendix synthesizes survey information according to these categories. The emphasis is on ranges and trends in interactive programs. In addition, references to particular activities are cited to illustrate the variety of interactive programs.

A. Cooperative Work/Study Programs

Cooperative engineering education programs are flourishing. In baccalaureate engineering programs, the number of schools offering a cooperative curriculum has increased from 27 to 153 between the years 1950 and 1970 [1]. Not all industries are willing to support such programs, but those that do, cite the following reasons for their participation: facilitation of recruitment, enactment of corporate responsibility, productivity of student employees. As an index of the degree to which industry is receptive to establishing a cooperative program, the experience of the University of the Pacific is relevant. This school is small; it has ten engineering faculty and two departments, civil and electrical. In 1969, during a period of retrenchment on the part of major employers of engineers in California, the University of the Pacific contacted roughly 100 industries in the state to determine their interest in participating in a new cooperative education program. Sixty percent responded affirmatively [2]. Indeed, in the period 1969 to the present, the University has revitalized its engineering program by energetically building its curriculum around the cooperative program [3]. During this period of declining engineering enrollments throughout the nation, Pacific's enrollment has grown from 55 to 150.

A cooperative engineering program can also provide a key communication link between schools and industry. At the University of California, Berkeley, a plan for faculty members to visit cooperative students at their industrial locations is being considered. The intent is to foster additional contact both between students and faculty and between industries and faculty [4].

A further use of cooperative education is to increase minority enrollments in engineering. A program at The University of Connecticut is being developed toward this end with the support of Connecticut's Commission for Higher Education [5]. Many industries are particularly receptive to such programs as vehicles for affirmative action.

B. Continuing Education Programs

Although the notion of maintenance of technical vitality is taken as axiomatic by some industries, others view continuing education for their engineers as irrelevant. This latter view is more typical of industries on the extreme edges of the technology spectrum. High technology industries view themselves on the cutting edge of development; they are ahead of the schools. Low technology industries see little need for continuing education; productivity and advancement depend on performance on the job, not on advanced degrees.

On the other hand, the overall industrial trend is toward increased participation in continuing education on the part of engineers [6]. Such education is provided either at proximate schools or in-house. A recent (1973) American Chemical Society survey of employee benefits provided by 223 United States employers of chemists and chemical engineers [7], shows that 96% of these companies reimburse their employees for at least part

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of the cost of part-time continuing education in job-related courses at approved schools. Of the companies that do, 61% pay 100% pf the tuition cost, and 21% pay 75 to 90% of this cost. The remaining 18% pay a smaller percentage of the tuition cost or have no set practice.

This same survey also revealed a significant involvement in in-house continuing education. Nearly 20% of the 223 companies surveyed, offer in-house courses for their technical staff. Typically, the larger companies engage in such activity: among those companies that had net annual worldwide sales of less than $10 million in 1972, only 6% offered in-house courses; among companies with net annual worldwide sales of $1,000 million or more in 1972, 42% provided in-house continuing education programs.

There is a growing trend toward providing continuing education on company time. At Sandia Laboratory, continuing education is viewed as an integral part of a person's job assignment [8]. Employees are allowed from 7-1/2 to 9 hours off per week for classes and travel. Academic achievement is formally recognized in Sandia's reward structure: an earned doctorate provides an annual salary increase of from $5000 to $6000. Sandia also sponsors a competitive program for its masters level people who wish to return to school for full time study toward the doctorate: this program pays for all tuition, relocation, and living expenses at the employee's preferred school.

In addition, there is a significant and growing trend toward providing continuing education via live television and recorded video tape [9]. Regular degree granting schools and commercial enterprise are actively marketing courses using these delivery systems. At Sandia and Lawrence Livermore Laboratory, both located at some distance from major educational institutions, there is wide use of televised courses provided by Stanford, the Berkeley and Davis campuses of the University of California, and by Chabot College. Sandia enrolled roughly 800 students in over 100 different courses in 1973; they can run a given course for a single student, if necessary. At Lawrence Livermore Laboratory, the oral qualifying examination for the Ph.D. can be conducted via remote television. Indeed, at Lawrence Livermore, it is possible to go from a high school education through the Ph.D. while maintaining employment. Likewise, at Bechtel, an engineer can earn an advanced engineering degree or an M.B.A. via remote television.

Lastly, there is a small but growing trend toward integrating the continuing professional education of technical staff with personal growth and development [10]. In addition, continuing education is being provided to sub-professional workers. At General Electric's Nuclear Energy Division, educational opportunities include courses in Transactional Analysis, Effective Listening, and Understanding Cultural Differences. Such opportunities for employees are facilitated by community college offerings which are conducted on industrial premises. For example, Foothill College offered the following courses in the fall, 1974, at Hewlett-Packard: Principles of Accounting, Introduction to Microwave Electronics, Guidance for Continuing Education for Women, and Semiconductor Device Processing [11].

Cost data on industrial expenditures for education are difficult to obtain and interpret. Many companies view this information as proprietary or do not compile it. Some data have been obtained, however, and are presented here to indicate order of magnitude spending.

Kodak spent about $1.3 million in 1973 on tuition reimbursement for 3,260 employees.

General Electric's Research and Development Center spends roughly $35,000 annually on tuition reimbursement for 90 employees.

The City of Palo Alto pays approximately $450 per year per employee for job related professional development expenses, including tuition, books, journal subscriptions, or conference fees.

Siltec spends roughly $10,000 per year for education; most of this money goes toward management training courses for their 14 engineers and 450 production workers.

General Electric's Nuclear Energy Division spends roughly $600,000 for its continuing education, training, and tuition reimbursement programs. The division consists of approximately 4,500 people of whom roughly 2,500 are professionals.

Bechtel spent $660,000 in 1973 for educational programs for their staff of approximately 4,600 technical people, of whom roughly 3,500 are engineers.

Sandia Laboratory, Livermore, spends about $100,000 per year on education exclusive of salaries and capital expenditures. Of this amount, roughly $12,000 goes toward tuition reimbursement and roughly $40,000 goes toward televised courses.

Lawrence Livermore Laboratory spends an amount equivalent to roughly 2% to 3% of the salaries of professional staff for continuing education.

Shell Development has calculated the cost for its in-house educational offerings. This cost amounts to a "tuition charge," and includes facilities, computer time, and educational staff, but does not include travel or salaries of students: the number is approximately $450/student/week. Overall, this in-house expenditure for education amounts to roughly $1 million per year for nearly 1000 professionals. (Shell has also offered a course in offshore technology to outsiders; this course was sold at the rate of $100,000 per student.)

C. Consulting Relationships

Consulting of faculty members for industry is an activity school administrators encourage to a degree. Some schools limit consulting time to one day per week for an individual faculty member. Occasionally, schools have established "industrial affiliate programs" in which industries contribute a set fee per year. This fee can sometimes be applied toward limited consulting activity. The University of Texas, for example, allows this option and also provides unlimited utilization of their continuing education offerings for the fee of $10,000 [12].

Industries, in general, do not encourage their employees to consult. Usually, there exists a formal agreement between employee and employer which expressly prohibits such activity unless it can be clearly demonstrated that the consultation lies outside the realm of company activity.

When an industry seeks the assistance of a consultant, this person is normally located through peer contact. A person within a company may know of an individual with a particular expertise, usually because of his published work or his teaching reputation. Contact generally flows from the company directly to the consultant. Occasionally, a school administrator will receive an unsolicited inquiry asking for a faculty member with particular expertise, but such initiation of consulting relationships is relatively rare.

D. Research Programs

Industrially funded contract research at schools occurs, but in much smaller measure (perhaps 5%) than that funded by government and the foundations [13]. When industry does fund a project, it usually is one that a particular faculty member has initiated. Industry rarely chooses schools to undertake research in which answers are needed quickly. When a company recognizes a research need, it acts more promptly and more directly than is possible within typical academic structures. On the other hand, if a faculty member can show a relationship between research he is undertaking and an industrial need, such activity can be subsidized occasionally.

The question of whether research of the highest quality or productivity occurs in industry or in schools is, of course, moot. Former Dean of Engineering at the University of California, Berkeley, John Whinnery, cites examples of fundamentally important research generated in both camps. Schools produced the computer and the laser; industry developed the transistor. Each of these examples illustrates that both schools and industry do produce significant advances.

The NASA-Ames University Consortium constitutes a novel basis for implementing collaborative research projects between school faculty and NASA scientists and engineers [14]. Although the consortium administers other programs, research is the primary activity. In 1973, the consortium administered $1.4 million in 133 exchange agreements with nearly 40 schools.

The emphasis in all agreements is in collaborative exchanges. Sometimes the exchanges are based on equipment, but the major thrust of the interaction .' based on people. The philosophical basis of the program is to make the federal laboratory a part of the school, and vice-versa. Often, students are directly involved in the exchange agreements.

E. Design Projects*

There is a growing industry/school interaction in the area of design projects and system studies [15]. In such programs, industry typically presents a real problem, supplies money, material, and expertise, and students work on the problem with varying degrees of faculty support. Some schools and industries have developed formal programs of interaction along these lines; others proceed on an ad hoc basis. An example of the former is Dartmouth College's Partnership Program. An example of the latter is the program in the Stanford Design Division.

As the engineering curriculum seeks a closer connection to the real world, such programs of interaction will increase. There is a virtually unlimited supply of significant industrial problems to challenge students. The primary problem in initiating such activity lies in providing incentives to faculty to seek out such problems.

The design project area is one, however, which can be tied readily to other forms of school/industry interaction. For example, if schools sponsor industrial advisory committees to advise on curricular matters, such groups can be asked to supply ideas for projects or to judge completed ones. Likewise, if faculty have occasion to visit industries on other business, the matter of stimulating ideas for design projects can easily be appended.

F. Exchanges of Personnel

Many faculty members spend periods of time working in industry, although such activity is not as extensive as it might be, due primarily to a lack of incentive for the faculty member. Industrial sabbaticals are less favored among school faculty than are research sabbaticals. Nonetheless, the Ford Foundation program which enables young engineering faculty to spend a year in industry accents the need for such interaction, particularly among faculty with little or no industrial experience.

A limited number of industries hire school faculty in the summer. For example, Lawrence Livermore Laboratory hires roughly 25 to 30 faculty from around the country each summer. This program brings new theoretical concepts and methodologies to the laboratory and indirectly assists the laboratory in recruiting students.

John Whinnery, former Dean of Engineering at the University of California, Berkeley, maintains that industrial sabbaticals are often more valuable than academic research sabbaticals. He has observed dramatic shifts in research and teaching direction by faculty after an industrial sabbatical. In addition, Dean Whinnery notes that Berkeley's Electrical Engineering Department of 65 to 70 people normally contains a complement

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*See also Appendix 3.

of 6 or 7 individuals who are on loan from industry. The companies which provide such people are typically large high-technology ones, and the persons provided to schools are usually senior scientists or engineers. Industries which have granted leaves of absence of this kind include American Cyanamid, Avco, Du Pont, General Electric, Hercules, Kodak, Mobil, Monsanto, Philip Morris, Rand, Schlitz, and Weyerhauser [16].

There is some movement in the direction of appointing faculty members from the ranks of industrial practitioners. The University of California, Berkeley, and Stanford University both cite recent examples [17,18]. Such appointments are relatively rare, however, due to several problems. First, there is the difficulty in documenting an individual's productivity in an industrial setting. Second, there is the problem of salary differential. Third, there is no strong communication network between industries and schools. In addition, there is some risk to schools which encourage exchanges of their faculty with industry. A high percentage (roughly 50%) of faculty who leave the academy for a limited period decide not to return [19].

G. Special Programs

Here we might include student internships and summer jobs in industrial locations. In addition, the Student Competitions on Relevant Engineering (SCORE) might be cited. These competitions have included the Clean Air Car Race and Students Against Fire, and feature a considerable degree of school/industry interaction.

Case studies based on real industrial problems and solutions should be noted. Case studies can illustrate in the classroom the kinds of things that engineers do and illuminate the environment in which they work. Also, case studies can be written by students. In this format, the engineering student acts as an historian, often reliving the case with the engineers who were directly involved in the original project. The Stanford Case Studies Library serves the engineering education community as a clearinghouse for such materials.

Some schools have initiated Industrial Affiliate or Industrial Associate programs. In such programs, industries contribute, sometimes on a sliding scale depending upon their size, an amount ranging from roughly $300 to $15,000 per year. For this amount, the industries learn of relevant research results, are invited to contribute design project problems, receive special educational benefits or offerings, and are provided special access to faculty and students or limited consulting benefits. Stanford University conducts such programs, and some departments provide an incentive to faculty to solicit industrial members (one half of the affiliate fee which is turned over to the faculty member for his use in educationally related activity; the other half goes into departmental funds).

In addition, some schools have encouraged product development activity on the part of faculty. For example, patent licensing agreements distribute proceeds to the faculty inventor, the academic department, and the school. In some cases, schools have developed offices for facilitating the development of patent licensing agreements between the school and industry. Examples include MIT, Carnegie Mellon University, and the University of Oregon.

Some schools and departments have established industrial advisory boards. Such groups are convened for the purpose of critically examining curricula and research directions. In such a format, a conference is sometimes scheduled during which recent research activities are described, design projects are displayed or judged, and formal input on curriculum decisions is sought. Such boards can provide a natural vehicle for maintaining or generating contact with influential alumni.

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Appendix 5

INDUSTRY/SCHOOL INTERACTIONS

This appendix includes an analysis of the avenues of interaction between industries and schools. In addition, obstacles which impede the successful operation of specific programs of interaction are detailed.

The list below indicates the nature and extent of existing avenues of interaction. Items in the list have been ordered to show flows of people, money, and ideas. Many avenues of interaction are associated with more than one type of flow. For example, students working in coop programs represent a flow of all three: people, money, and ideas. However, for brevity, the list is constructed to show a specific avenue of interaction only once.

AVENUES OF INTERACTION

FLOW DESCRIPTION	FLOW DIRECTION
PEOPLE FLOWS	
Students (before career entry)	
1. Students work in coop programs.	back and forth
2. Students work summers in industry.	back and forth
3. Students graduate from schools and go to work in industry.	from schools to industry
Engineers in Industry (after career entry)	
4. Engineers take leave from industry for temporary study at schools.	back and forth (company paid and nonpaid leaves)
5. Engineers become part-time students.	back and forth (in-plant or on-campus students)
6. Engineers become part-time teachers or researchers at schools.	back and forth (in-plant or on-campus adjunct professor or lecturer)
7. Engineers take leave from industry to teach or do research full time at schools.	back and forth (company paid or otherwise; visiting professor)
8. Engineers leave industry to take permanent faculty positions.	from industry to schools

FLOW DESCRIPTION	FLOW DIRECTION
Faculty of Engineering Schools	
9. Faculty teach or consult part-time in industry.	back and forth
10. Faculty work summers in industry.	back and forth
11. Faculty leave schools to work full-time temporarily in industry.	back and forth (sabbatical or other leaves)
12. Faculty leave schools to take permanent positions in industry.	from schools to industry
MONEY FLOWS	
13. Industry pays taxes that in part support schools.	from industry to schools
14. Industry gives unrestricted money to schools.	from industry to schools (pure charity, public relations, community service, etc.)
15. Industry gives designated money to schools.	from industry to schools (special building funds, library, scholarships and fellowships, endowing chairs, affiliates programs, etc.)
16. Industry gives equipment to schools.	from industry to schools (new, used, and obsolete equipment)
17. Industry enters into specific contract work at schools, or supplies problems for student projects	from industry to schools (research, use of special facilities, etc.)
IDEA FLOWS	
18. Industry and school staff publish in open literature.	back and forth (schools generally more basic and less applied while industry generally other way; BUT no clear domains)

FLOW DESCRIPTION	FLOW DIRECTION
19. Industry uses educational material from schools.	from schools to industry (books, notes, and packaged course materials developed at schools; industry also uses such developed in-house and developed by nonschools)
20. Industry provides (at least the basis for) case study write-ups.	from industry to schools
21. Industry engineers offer advice on school matters.	from industry to schools
22. Faculty offer advice on industry matters.	from schools to industry

The table shows ten avenues with back and forth flows, eight avenues (including all five of the money flow avenues) with flows from industry to school, and four avenues with flows from school to industry. Hence, the flow directions in the interactions are not as unbalanced as might be assumed. Industry receives substantial benefits from its interaction with schools.

Obstacles on the Avenue of Interaction

Each of the preceding avenues of interaction between schools and industry has obstacles that limit its use. Below, we specify some important obstacles for each avenue of interaction and show which obstacles affect more than one avenue of interaction.

(1) Students work in coop programs.

(a) Industry doubts that coop students really "earn" their salaries; hence, it is reluctant to initiate coop programs and tends to cut back on coop students during economic slowdowns.

(b) Many schools do not have coop programs, or, if they coop, they don't actively promote it. This may result from a general faculty attitude that coop experience can help to pay for education but that coop experience does not really contribute to undergraduate engineering education.

(c) Students can usually pay for undergraduate education without coop. Hence, with an implied faculty disinterest, many students decide against coop.

(d) There is some (unknown) upper limit to the number of engineering students in the U.S. who can reasonably participate in a coop. There are only 1-1.2 million engineers in the USA and there are about 240,000 undergraduate engineering students in the USA. If every engineering undergraduate entered coop on a 50% work - 50% school sequential time sharing, we would have an additional number of preengineers in industry equal to 10% of the engineering labor force. It is not clear that industry can (or would) absorb this large a number of coop students even if the students "earned" their salaries.

(2) Students work summers in industry.

(e) Industry doubts that summer students really "earn" their salaries; hence, few summer positions are available, especially during economic slowdowns.

(f) Most engineering schools have no organized programs to locate, create, or encourage summer engineering positions. Only the routine operation of the school placement office is available to assist students.

(3) Students graduate from schools and go to work in industry.

(f*) Although it appears that all engineering graduates can get jobs, it is by no means clear that there is always a good match of person and job. In particular, it appears that placement offices primarily serve the major industrial recruiters, and are generally unimaginative and unaggressive in their attempts to place students in challenging positions.

(4) Engineers take leave from industry for temporary study at schools.

(g) Such students are often discriminated against for scholarships and fellowships controlled by schools. Most companies lack company-paid educational leave programs.

(h) Often such a student realizes that his academic skills are rusty and hence he will be in a disadvantageous competitive position.

(i) There are few academic programs geared to the interests of returning students.

(j) Many academic programs are irrelevant and hence demotivating to a returning student.

(k) The practicing engineer believes that his company success depends on his job performance more than on his education.

(5) Engineers become part-time students.

(l) The work environment, together with family and civic responsibilities, leaves little time for this activity.

(m) No courses may be conveniently available without excessive commuting time or high personal expense.

(n) Part-time students are often discriminated against for scholarships and fellowships controlled by schools. Some companies do not reimburse tuition and other expense.

(o) Often such a student realizes that his academic skills are rusty, and hence he will be in a disadvantageous competitive position.

(p) Many times there are no academic programs geared to the interests of part-time students.

(q) Many academic programs are irrelevant and hence demotivating to part-time students.

(r) The practicing engineer believes that his company success depends on his job performance more than on his education.

(6) Engineers become part-time teachers or researchers at schools.

(s) There is some school resistance to this: there may be no bureaucratic mechanism to allow it.

(t) The school faculty may set credential requirements to make this most difficult.

(u) There may be no courses on the books that encourage experience-oriented teachers.

(v) The work environment, together with family and civic responsibilities, leave little time for his activity.

(w) No such position may be readily available without excessive commuting time or high personal expenses.

(x) If the engineer perceives his industrial success as depending wholly on his work activities, he will be unwilling to engage in such outside activities.

(7) Engineers take leave from industry to teach or do research full-time at schools.

(y) Often such a would-be faculty member realizes that his academic skills are rusty, and hence he will be in a disadvantageous competitive position.

(z) There may be no academic programs geared to the interests of such faculty.

(aa) Many academic programs are irrelevant and hence demotivating.

(ab) If a practicing engineer perceives his company success as dependent on his job performance, he will be unwilling to engage in outside activities.

(ac) There is some school resistance to this; there may be no bureaucratic mechanism to allow it.

(ad) The school faculty may set credential requirements to make this most difficult.

(ae) There may be no courses on the books that encourage experience-oriented teachers.

(af) Many engineering schools have more staff now than they really need.

(8) Engineers leave industry to take permanent faculty positions.

(ag) Often such an engineer realizes that his academic skills are rusty, and hence he will be in a disadvantageous competitive position.

(ah) There may be no academic programs geared to the interests of such engineers.

(ai) Many academic programs are irrelevant and hence demotivating.

(aj) The school faculty may set credential requirements to make this most difficult.

(ak) There may be no course on the books that encourage experience-oriented teachers.

(al) Many engineering schools have more staff now than they really need.

(am) The engineer may have to give up substantial pension rights.

(an) The engineer may have to take a pay cut.

(9) Faculty teach or consult part-time in industry.

(ao) Faculty, at schools where contact with industry does not count toward advancement in rank, salary, and social prestige, are discouraged from this activity.

(ap) Faculty who lack specific application-oriented knowledge have little to offer industry.

(aq) An inconvenient commute between school and the company will discourage this activity.

(ar) The school may not allow this type of activity.

(as) These activities may be better met for the company by using either in-house people or outside nonschool people.

(at) The company may not want to bring outsiders into the organization for security or proprietary reasons or because of corporate pride in the skills of their own employees.

(10) <u>Faculty work summers in industry</u>.

(au) Faculty at schools where contact with industry does not count toward advancement in rank, salary, and social prestige, are discouraged from this activity.

(av) Faculty who lack specific application-oriented knowledge have little to offer industry.

(aw) An inconvenient commute between school and the company, or a required relocation, discourages this activity.

(ax) The company may not want to bring outsiders into the organization for security or proprietary reasons or because of corporate pride in the skills of their own employees.

(ay) Faculty may have ongoing projects and students that make it difficult to leave.

(11) <u>Faculty leave schools to work full-time temporarily in industry</u>.

(az) Faculty at schools where contact with industry does not count toward advancement in rank, salary, and social prestige, are discouraged from this activity.

(ba) Faculty who lack specific application-oriented knowledge have little to offer industry.

(bb) An inconvenient commute between school and the company, or a required relocation, discourages this activity.

(bc) The company may not want to bring outsiders into the organization for security or proprietary reasons or because of corporate pride in the skills of their own employees.

(bd) Faculty may have ongoing projects and students that make it difficult to leave.

(be) Faculty may have to risk gaps in research funding, research students, or other academic activities.

(bf) Schools may need the faculty on the campus and may not let them leave for a year.

(12) Faculty leave schools to take permanent positions in industry.

(bg) Such faculty may have to give up substantial pension rights.

(bh) Faculty who lack specific application-oriented knowledge have little to offer industry.

(bi) Faculty may have ongoing projects and students that make it difficult to leave.

(bj) Faculty may have to give up substantial annual vacation time to make this move.

(13) Industry pay taxes that in part support schools.

(bk) Higher education is treated as a conglomerate unit in most states. Industry cannot lobby for more of its dollar to go to engineering schools.

(bl) State legislators and state boards of education are not sensitive to the importance to the state of effective school-industry interaction.

(14) Industry gives unrestricted money to schools.

(bm) There is increasing competition for this industry "charity" dollar.

(bn) Schools have not made a good case for their need and the worth of such gifts.

(bo) Schools have generally bad reputations for financial management, hence unrestricted monies are particularly hard to get.

(bp) There is not enough credit (public relations value) in such gifts.

(15) Industry gives designated money to schools.

(bq) There is increasing competition for this industry's "charity" dollar.

(br) Schools have not made a good case for their need and the worth of such gifts.

(bs) There is not enough credit (public relations value) in such gifts.

(bt) Industry may think what it is buying is not worth the price, e.g., an affiliate's program at $10,000 per year.

(bu) Unskilled fund raisers may push a particular company for the "wrong" type of designated gift, e.g., somebody may try to get company to endow a chair. The company may refuse to do this when they would have contributed heavily to a building fund, a scholarship fund, or to something else.

(16) Industry gives equipment to schools.

(bv) Industry is often willing to give only equipment that is obsolete and useless to the school.

(bw) Often schools must pay shipping charges they cannot afford.

(bx) Industry is willing to give equipment that is good but not valuable or useful to the school.

(17) Industry enters into specific contract work at schools or supplies problems for student projects.

(by) Industry problems are immediate and must be solved quickly.

(bz) Industry can't always protect the proprietary nature of its work in the open environment of a school.

(ca) There are occasionally problems associated with patentable results--usually for the industry to own such rights an a priori agreement has to be signed which results in an exorbitant overhead rate being charged.

(cb) If proprietary rights are protected, the faculty member may be denied the right to publish the results in the open literature. How significant this is, depends upon the faculty reward structure--see (ao) above.

(cc) University overhead rates often look high to industry.

(cd) These activities may be better met in the eyes of the company by using either in-house people or outside non-school people.

(ce) The company may not want to bring outsiders into the organization for security or proprietary reasons or because of corporate pride in the skills of their own employees.

(18) Industry and school personnel in open literature.

(cf) Industry is generally reluctant to publish in the open literature.

(cg) With the "publish or perish" attitude prevalent at many schools, faculty publish unnecessarily and tend to work on problems that will lead to publishable results; this tends to make faculty look irrelevant and blue-sky-oriented.

(19) Industry uses educational material from schools.

(ch) Industry needs tend to be applications-oriented, but school-produced educational material tends to be nonapplications oriented.

(ci) Other organizations (nonschool) are producing more and better educational material than schools.

(cj) Industry may feel that they can produce better (i.e., more sharply focused for a particular need) educational material themselves.

(ck) Industry may not perceive that they need any educational material.

(20) Industry participates in Case Study Programs.

(cl) Industry sees no advantage in prepared case study materials.

(cm) Faculty can't dig out the information from the industry unless they somehow learn about the case.

(cn) These may be proprietary, legal, or ethical issues of such a nature that industry will not let the details be made public.

(co) The case could be publicly embarrassing to the company.

(21) Industry engineers offer advice on school matters.

(cp) Schools don't value advice; hence, they don't seek this input, or, getting the input, don't act on it.

(cq) Industry people don't know what schools need.

(cr) The industry people who give advice tend to be presidents and vice-presidents of large companies. They have many failings--e.g., they are so busy they don't give this advice much careful or serious thought; their view of what schools ought to do is not the same as the view of engineering managers; etc.

(22) Faculty offer advice on industry matters.

(cs) Industry doesn't value this advice; hence, it doesn't seek it, or, getting it, choose to ignore it. (This parallels (cp) above.)

(ct) School people don't know what industry needs.

The relation between avenues of interaction and the obstacles is shown on Figure 20. The chart identifies 59 distinct obstacles. Because one obstacle may impede the flow on more than one avenue of interaction, the preceding table and the chart show 99 total obstacles on the several avenues of interaction.

We can interpret the chart or table in at least three ways:

(1) We can look at the chart and see a high density of points in the people flow of engineers and faculty. The high density shows that greatest number of problems are in these two groups; hence, that's where we ought to work the hardest to generate and to implement ways to overcome obstacles. For example, the obstacles of the paucity of academic programs geared to the interests of returning engineers and the presence of much irrelevant and demotivating material in academic programs is one that engineering schools, with help from industry, can tackle. More individualized instruction, project activity, better guidance, more frequent review of course material, use of more industrial faculty, etc. might all be possible solutions.

(2) We can look at the chart or table and see which avenues have the fewest obstacles. Then we could create ways to overcome those obstacles and thus increase the flow along the cleared avenues. For example, we identified only two obstacles to student summer work in industry. Engineering schools could readily organize a program to locate, create, or encourage summer engineering positions and thus remove one obstacle. Industry and engineering schools could cooperatively work on the second obstacle--industry doubt that students earn their salary--perhaps by considering long-term benefits or perhaps by developing school programs that give students more marketable skills while they are undergraduates.

(3) Alternatively, instead of starting with the chart and then deducing where or what we should attack, we can independently recommend changes in the system. The effect of the recommended change can be then evaluated in terms of how many points it would erase if implemented. Thus, we can use the chart to evaluate the impact of the recommendations. If we know the cost of implementation of the recommendation, then we can rank the cost/benefit of the recommendations aimed at improving the interaction between schools and industry.

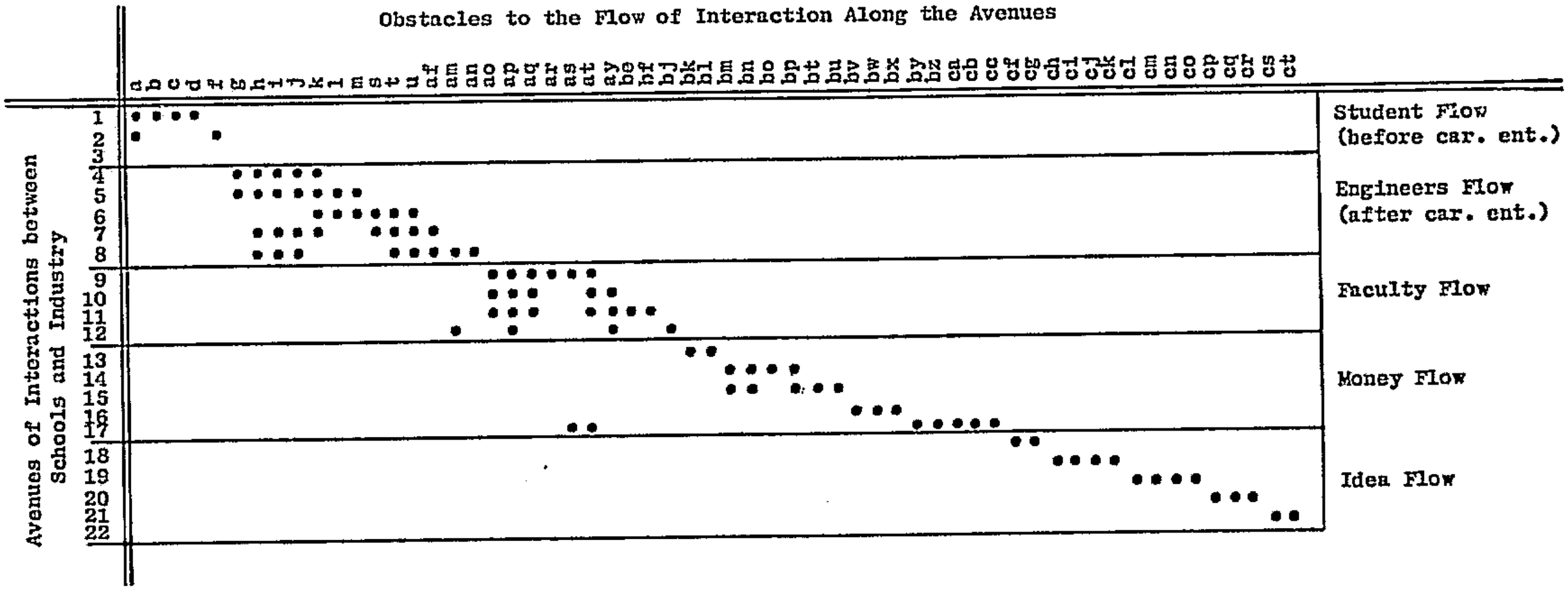

Figure 20. AVENUES AND OBSTACLES FOR INTERACTION.

Appendix 6

TEXAS FUNDING FORMULAS

A. The Formulas

The Texas Coordinating Boards which devised the Texas formulas started classifying all the elements of institutional costs. Then they compiled the accepted costs in the Texas College and University system and in sample schools across the United States. Formulas to compute cost were then constructed empirically, and a regression analysis was performed to determine if a correlation is possible over a wide range of schools. Where good correlation existed, the formula obtained were and are used to determine the funds requested from the Texas legislature for the following biannual funding period. When the Coordinating Board found that no formula correlated well, then no formula was given for the particular budget item and a separate request and justification to the legislature must be made for that item by each college and university. An estimate for such items is usually based on the actual expenditures by the University of Texas at Austin during Fiscal year 1970. The Coordinating Board also tempers its requests according to how it senses the current mood of the legislature. The legislature usually funds 85 to 95% of the level of the formula.

A significantly higher instructional cost is allocated to engineering than to many other disciplines. The increased cost is reflected in the formula in the Faculty Salaries, Departmental Operating Expenses, and Organized Research Categories. This increased cost is due to three factors:

(1) higher faculty salaries to compete with industry

(2) expensive laboratory instruction required

(3) smaller classes traditionally used in engineering

The formulas used for various elements of institutional costs and the resulting dollar values for the University of Texas are shown in Table 14.

B. Discussion

Table 15 lists the formula-derived costs per student semester credit hour. Note the rapid increase in cost for masters and doctoral programs over undergraduate instruction. Tuition at most state universities is $20 to $25/SCH* and covers 1/4 the cost of undergraduate instruction and a much smaller fraction at the graduate level. Masters

*Semester credit hour.

Table 14

UNIVERSITY OF TEXAS FORMULAS (1970) FOR VARIOUS ELEMENTS OF INSTITUTIONAL COSTS

Element	Method of Computation	Formula
1.* General Administration and Student Services	Calculated	$72 per Student + 7-1/2% of Sponsored Research Funds + 0.3% of Total Educational and General Appropriations the previous year
2.* General Institutional Expense	Estimated or Designated	Estimated as Equal to Item 4c or 6% of Faculty Salaries
3.* Staff Benefits	Estimated or Designated	Approximated from Budget as 3% of Faculty Salaries
4. Resident Instruction a.** Faculty Salaries	Calculated	$30 per Undergraduate SCH, $83 per Masters SCH, $241 per Doctoral SCH
b.** Departmental Operating Expense	Calculated	$11 per Undergraduate SCH, $25 per Masters SCH, $113 per Doctoral SCH
c.** Instructional Administrative Expense	Estimated or Designated	Reported as 6% of Faculty Salaries
5.* Library	Calculated	$2 per Undergraduate SCH, $4 per Masters SCH, $17 per Doctoral SCH
6.** Organized Research	Calculated	Faculty Salary $\times \frac{0.015U + 0.5M + 6.D}{U + M + D}$ + 4% of Sponsored Research Funds Expended During Previous Year***
7. Extension and Public Service	None	Considered Self Supporting
8. Physical Plant Operation and Maintenance	Estimated	Estimated at $5 per SCH when Half the Total Costs are Attributed to Research and Half to Education
9. Major Repairs and Rehabilitation of Buildings and Facilities	Estimated	Estimated at $20 per SCH

*University Wide Formula.

**Engineering Only.

***Separately Budgeted Research Usually Financed Externally.

U = Undergraduate FTSE (full time student equivalent or student taking 15 credits per semester). M = Masters FTSE. D = Doctoral FTSE.

****The estimate approximates rental cost of facilities. Land acquisition is not included. Half of the area is assumed to be used for research and half for instruction.

Table 15

APPLICATION OF FORMULAS ON A SCH* BASIS USING FISCAL YEAR 1973 DATA

Engineering	Undergraduate $	Undergraduate %	Masters $	Masters %	Doctoral $	Doctoral %
Faculty Salaries	30	40	83	39	241	13
Department Operating Expenses	11	15	25	12	113	6
Library	2	1.5	4	2	17	1
General Administration and student services, $72/student/yr ÷ 30 semester hrs	2.5	3	2.5	1	2.5	0
Organized Research (from directly applying formula factors of 0.015U, 0.5M, or 6D to faculty salary)	0.5	0.5	41.5	19	1446	78
Staff Benefits, 3% of Faculty Salaries; Gen. Instructional & Institutional Administration, 12% of Faculty Salaries	4.5	6	12.5	6	36	2
Physical Plant Operation and Maintenance	5	7	5	2	5	0
Building and Facilities, equivalent rental cost	20	26	20	9	20	1
	$75.5	100%	$213.5	100%	$1881.0	100%

*Semester Credit Hours. Note that the calculations in the appendix on teaching methods are in quarter credit hours. For comparison, a factor of 2 must be applied to semester credit hours.

level instruction is more expensive because of smaller classes and increased faculty preparation. Doctoral level instruction is even more expensive, because the instruction is tutorial, and a large amount of organized research support is required by the student. This research support is usually funded externally and not by the state legislature.

Terman [14] points out that Masters program costs need not be significantly higher than undergraduate instruction if the program is large enough to maintain comparable class sizes. Terman [14] also states that Ph.D. programs are not expensive to the university, since the research support for both student and faculty is usually paid for by outside grant and contract funds. Terman quotes a figure of $50,000 to $80,000 in sponsored research expenditures for each Ph.D. produced. This amount agrees well with the Organized Research cost of $1,446/SCH from Table 9 when approximately 40 SCH of research are needed for a Ph.D.

It is interesting to include in the discussion the cost to the student, including wages lost while in school. For example, a typical undergraduate spends 3 hours per week for each semester credit hour taken for 16 weeks or a total of 48 hours/SCH. If the student could otherwise earn $3/hour, he is sacrificing

$144	for time and
10	for materials
$154/SCH	

This is double the institutional cost/SCH.

Masters or doctoral students give up a higher wage, perhaps $6/hour. Their cost would then be double or $308/SCH. The doctoral student is usually paid on a research-supported assistantship or fellowship, so a portion of the student cost is already included under the Organized Research classification.

C. Use of Model to Demonstrate Cost Savings

The use of the models can demonstrate possible savings from various proposals for cost cutting. Each of the following proposals is recommended as an area for possible cost cutting.

1. Decrease Student Time Required Per Course

Any economy obtained by cutting the student time required for education would be especially significant. With the undergraduate student cost of $154/SCH and the instructional cost of $76/SCH, the student cost is 67% of the total. With a 15% cut in student time, a 10% cut in the total cost of education could be obtained. Such an increased efficiency in the use of student time might be possible through:

(a) using the most effective teaching method for each particular student

(b) improved student selection and advising

Present funding policies which are based on student credit hour loads discourage these economies.

2. Smaller Physical Plant

The school physical plant might be reduced in size by 40% by using classrooms and labs two shifts a day throughout the year and by shifting as much instruction as possible off campus to student homes and dormitories. Combining laboratories can also reduce the physical plant. Since physical plant expenses are 33% of undergraduate costs, this would result in a net 13% saving in total cost. Unfortunately, most schools already have a large physical plant, and it is not easily disposed of. This would be an important cost to consider in any new or expanding school.

3. Increase Faculty Productivity in Teaching

An increase in faculty productivity, say, by 30%, might result from a new instructional technique, using course materials prepared at another school, combining similar classes with a neighboring institution so that duplicate courses would be eliminated, or by the use of educational technology to extend each faculty member's capability. (See Appendix 3.) Since faculty salaries and Administration are 46% for both undergraduate and masters level instruction, a 30% productivity increase would produce an 19% saving in total cost.

4. Give Faculty More Nonprofessional Support

This example assumes that increasing technician and secretarial staff will free faculty time for more professional duties. If faculty productivity is increased 30% by increasing the department operations budget by 50%, a net saving of 5% is obtained for undergraduate or masters level instruction.

5. Increase Efficiency of Committee System

Assuming that committees take 10% of a faculty member's time and that the productivity of committees could be increased so they would take only 5%, then the net cost of undergraduate or masters level education would be reduced by 2%, if the time saved could be converted to other productive work.